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EDITORIAL.

ITEMS AND NOVELTIES.

The Woodson Steam Boiler.—The boiler, of which we herewith present a plate engraving, though containing no essentially new features, yet seems to possess a happy combination of several devices which are universally acknowledged to be of advantage.

The following description, condensed from a more elaborate one, in a contemporary, will serve to explain its construction.

It is based upon the principle that uniform longitudinal circulation will furnish steam at the surface of the water with a uniformly accumulating pressure, and will keep the boiler of very nearly the same temperature throughout its length, thus avoiding the manifold evils which result from the repeated unequal expansion of its different parts. This principle is applicable to boilers of all kinds, while the engraving represents its application to a locomotive boiler.

The inventor, Mr. F. A. Woodson (243 Broadway, New York), seeks to accomplish these desiderata by the attachment of a longitudinal pipe, six inches (more or less according to size of boiler) in diameter, below the boiler proper, and a mud-drum for the deposition

and retention of sediment. The water passes from the end of the boiler remote from the furnace downwards into the mud-drum, thence onward through the pipe to the water-leg at the rear of the furnace, thence upwards into the boiler, delivering up its steam on its passage back again.

The passage of the water through the circulator will be more rapid as the temperature in the furnace is higher, but in all cases it is claimed to be rapid enough to change the entire body of water in a short time. Our cotemporary pays a high compliment to the satisfactory manner in which the circulation is performed, as well as to the removal of the sediment.

The inventor further claims an improvement in evaporative power by the construction of the furnace. The grate, as will be seen on inspecting the plate, is inclined, the highest part being front; the coal thus feeding backwards of its own gravity. A descending bridge-wall, into the interior of which water is flowing, intercepts the uncombined gases generated in the front chamber, while an additional air supply permits of their complete combustion in the second.

Shaw's Compound Propeller Pump.—This invention is the subject of two patents, dated Feb. 15, 1870, and May 30, 1871, and is owned by the Hydrostatic and Hydraulic Company, of Philadelphia, Pa.; office, 67 North Front street. The pump shown in illustration is 36 in. in diameter, and will throw from 25,000 to 30,000 gals. of water per minute, and is designed for drainage purposes, to be used below Delaware City.

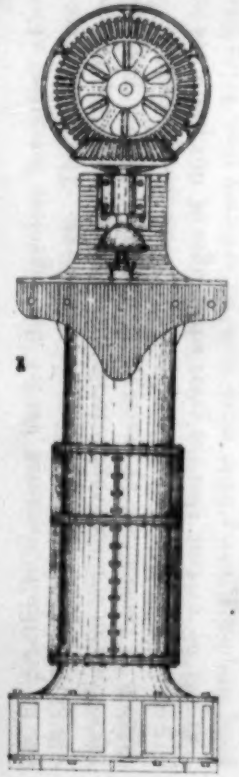
The invention consists of an ordinary pipe, constructed of two semicircular sections for the convenience of access to the interior, upon which sections are cast wings of propeller configuration, two feet apart, between which are rotated upon a shaft, *N* (passing through centre of pipe), ordinary propeller wheels of reverse angle; the combined action of the male thread of rotating propeller and the female thread of stationary wing elevates the water in proportion to pitch of thread and velocity of screw.

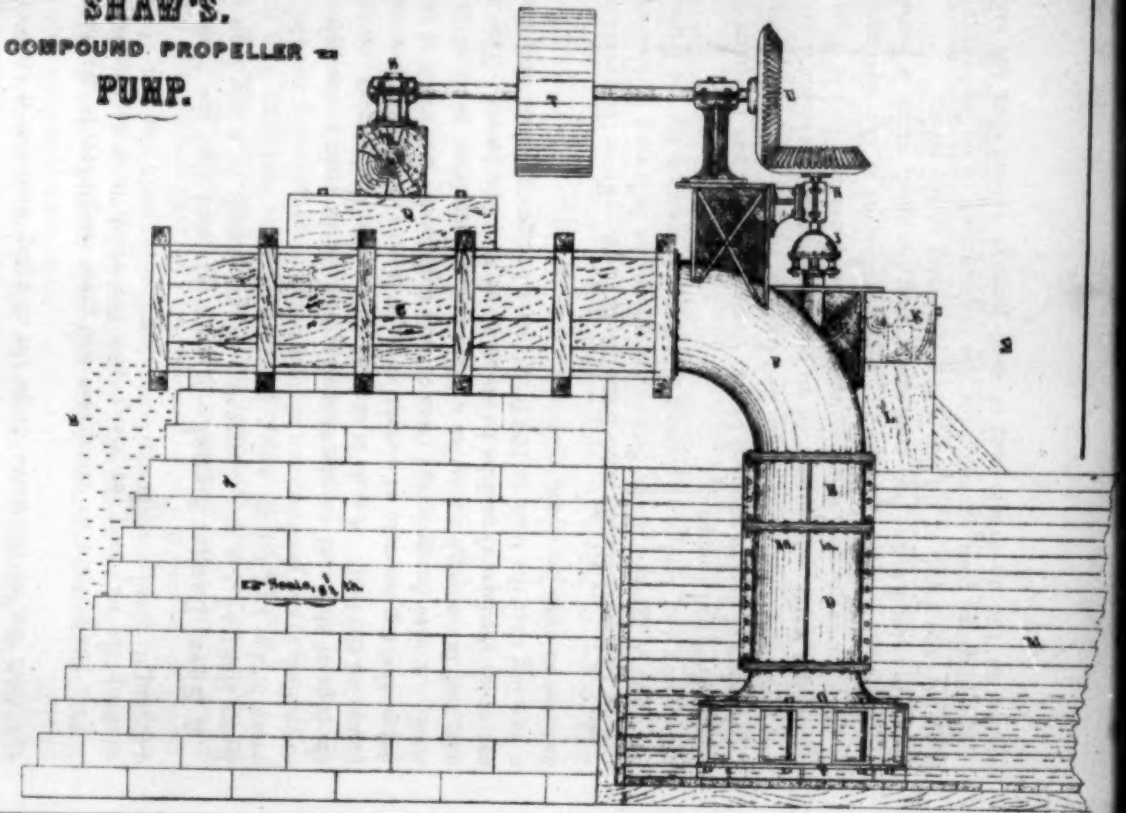
The basket, *O*, is intended to keep out objects too large to pass through the pump; the bend, *F*, leads the water into conduit, *C*, through which it is conducted into the river, *B*. *J* is a hydraulic disc to sustain the end thrust of shaft, as it will be observed that the weight of gearing, shaft and water must be sustained whilst rotating, giving an enormous end thrust in pumps of great length, which could

SHAW'S.

COMPOUND PROPELLER

PUMP.





not be practically sustained but for this ingenious invention, which will be illustrated more fully in our next issue. The power is conveyed from an ordinary engine to the pulley on counter shaft, *T*, from which it is transmitted by gearing, *U*, to shaft of pump. The velocity of pump shaft ranges from 150 to 200 revolutions per minute.

It will be evident that the great advantages of this pump are its great simplicity, being little more than an ordinary pipe, being free from valves and complicated machinery, not liable to be clogged by ordinary rubbish, and can be exposed in cold situations without damage from ice, as the water drops out of pump whenever it ceases to rotate.

This pump, from its cheapness and great simplicity, is gradually working its way into the many uses for which it is so admirably adapted.

A Novel Danger Signal.—We are informed that the Hudson River Railroad Co. has constructed danger signals of a new kind at every bridge and tunnel along its route, to warn brakemen who are compelled, in the performance of their duties, to occasionally run along the tops of the cars on the near approach of the train to dangerous places on the line. A pole is erected at the side of the track, carrying at the top an arm at a right angle to it, and projecting over the road. A wire fringe hangs from this, having nearly the width of the car, and low enough to strike a brakeman on the front piece of the cap or on the face, should he be standing as the train passes. This is a warning that the train is 100 feet from a bridge or tunnel, and that he must at once lie down.

The Council Bluffs and Omaha Bridge.—From the report of the Chief Engineer, T. E. Sickels, we glean the following particulars concerning the bridge at present in course of erection for the Union Pacific Railroad Company:

The plan of bridge adopted by the Company comprises 11 spans of iron superstructure, each span 250 feet in length, elevated 50 feet above high water, and supported on one stone masonry abutment and 11 piers formed of cast iron columns, eight and one-half feet in diameter, filled with cement masonry. The foundations of the abutment and piers extend to the bed rock underlying the sand, which is found at an average depth of 60 feet below low water in the river.

The original plan provided for the construction of an ice-breaker column on the up-stream side of each pier, to extend from the bed

rock to high water level, but this was subsequently abandoned as not essential to the safety of the bridge.

A contract for the construction of the bridge was made with L. B. Boomer & Co., of Chicago, in 1868, and the work of sinking iron columns for piers was commenced in February, 1869. The work was afterwards suspended for a period of eight months, and was resumed under a modified contract, which stipulates that the work of sinking columns and erecting superstructure shall be done under the management of the engineer of the railroad company, all the iron work to be manufactured and furnished by the contractors above named.

Since the resumption of the work in April, 1870, the work has been vigorously prosecuted. Ten steam engines have been in use for a greater part of the time, to operate the pneumatic machinery, hoisting cylinders and the iron work of the superstructure into position, &c.

The portions of the iron columns below water were cast in sections of 10 feet each, with internal flanges at the ends, by which means the sections could be securely bolted together. A red lead joint was used to make them air-tight. The wrought iron portion of the column (above high water) is also in sections of ten feet, fastened together by rivets. The thickness of the iron in this portion varies from one-half inch at the bottom to three-eighths at the top. The thickness of the cast-iron portion is one inch and a half. The process of sinking iron columns is similar to that which has been largely used in Europe and in India, and for a few bridges in this country. After sinking as far as possible, the water within the column is expelled by air pressure furnished by a steam pump, and the interior was excavated by laborers to within about two feet from the bottom, when the air pressure was withdrawn and the sinking continued further. The greatest pressure to which the men were subjected was 54 lbs. per square inch in excess of the atmosphere; but, though this is without parallel in work of a similar character, we are informed that they suffered neither injury nor inconvenience.

All the piers are built up to the full height except two, and those are above the level of high water. Four spans of the superstructure are in position, and the remainder will be completed and the bridge ready for use by the 15th of February.

The total cost of the bridge, with the approaches, is estimated to be, in round numbers, $1,650,000, of which, up to Dec. 1st, $1,300,000 have been expended.

A Machine for Testing the Strength of Materials.—Messrs. Riehle Bros., of this city, are building machines, of very simple construction, for this purpose. The plan adopted is that of a weighing machine. Though compact, it is exceedingly powerful, and may be adjusted with the utmost nicety, in order to test with equal accuracy the amount of strain which any given sample of boiler-plate or other metal may be able to withstand. The tool for holding the test pieces is modified in such a manner as to be adapted for a variety of purposes, such as the testing of cast and wrought iron-boiler-plate, girders, bolts, chains, &c.

The machine has already attracted much attention, and several orders are now being filled for establishments in other cities. A number of very satisfactory tests we understand have already been made for the Baldwin Locomotive Works in testing boiler-plate.

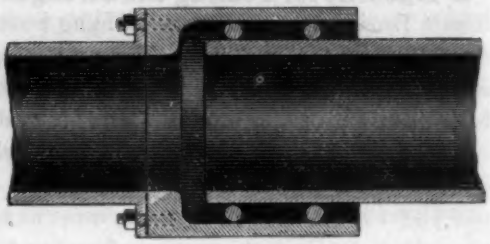
The Detroit Tunnel.—The following description of the present condition of the work of excavating a tunnel under the strait separating Detroit, Mich., from Windsor, Canada, has been published:

A large coffer-dam, forty feet square, has been constructed by driving down in double rows thick piles, upon which six inch planks were bolted. A solid pier was then formed by ramming in hard blue clay, and through this newly made land the shaft is to be sunk. The base of the iron shaft, fifteen feet in diameter, two feet thick and weighing eight tons, has been placed in position, and upon it brick work, laid in asphalt, has been built to the height of ten feet. The weight of the iron base and brick work will gradually sink the shaft to the required depth of fifty feet, as the earth is taken from beneath. When the bottom is reached the next work will be the excavation of the drainage tunnel, five feet in diameter and twenty-five feet below the main tunnels, at the respective entrances, but rising gradually to the central point.

Mechanical Problem.—Required the construction of a valve and its accompanying parts, so that its extreme movement in either direction need not exceed the width of one of the ports; the width of the port being considered equal to one-half the movement of the valve. By the accompanying parts is not meant the gearing or mechanism for operating the valve, but such devices—as slides or openings—as are necessary for solving the problem. D. V. W.

An Expansion Joint.—We find in an engineering contemporary the accompanying illustration and description of an expansion joint

for steam pipes, which seems to be a very suitable method of attaining that object.*



From the writer's statement, it appears that in a long line o steam-pipe, arranged to use exhaust steam for heating purposes, the expansion and contraction was so great as to frequently rupture the joints; and to obviate the difficulty, the form of expansion joint, shown in the above cut, was devised, which, we are told, obviated it entirely.

The two round rubber rings between the outside of the pipe and the inner side of the sleeve, serve as a packing and roll as the pipe expands or contracts. The rings are made of pure rubber, and of a sectional diameter $\frac{1}{8}$ inch greater than the space between the pipe and sleeve.

On Tilghman's Process of Cutting Hard Substances.—The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, for the promotion of the mechanic arts, to whom was referred for examination Mr. B. C. Tilghman's method of cutting and engraving stone, glass, &c., by a blast of sand, report that they have seen the operation as described in the "Journal of the Franklin Institute," for March, 1871, No. 542, pp. 195 to 197. The invention seems capable of extensive use in the arts. Some of the products of the invention seem to present new and valuable features. Glass ornamented by this process can only be compared with that etched by powerful acids, yet the entire absence of all undercutting, no matter how deeply the glass is cut, renders it superior. The great merit of the invention consists in its extended utility. By means of this sand blast effects have been produced which would be hard to imitate by any other known mechanical process, and with an ease and precision truly remarkable. They consider the invention original and of the highest utility, and deem it worthy of any mark of approbation you may see fit to bestow upon its originator.

With this in view, we would respectfully suggest that the Elliott

* Engineering xiii. 8.

Cresson medal of the Franklin Institute be awarded to Mr. B. C. Tilghman, in accordance with the rules governing such award.

All of which is respectfully submitted.

Coleman Sellers, Samuel Sartain,
Charles M. Cresson, M. D., Wm. Struthers.

Breaking up Large Castings.—Mr. P. Champion has experimented upon the use of dynamite for breaking up large masses of metal for subsequent fusion, and announces his results as satisfactory. The author suggests that a number of holes be bored in the mass, and that the charges in each be connected with each other. The explosion of all of them may then be effected simultaneously by means of electricity, and the mass reduced at once into fragments suitable for immediate use.

Cement for Joining Iron.—As a cement for joining pieces of cast-iron or stopping fractures, Winkler recommends the use of the following mixture: Sixteen parts of clean wrought-iron filings, three of powdered sal-ammoniac and two of flowers of sulphur.

When intended for use, it is recommended to reduce the dry mixture (which can be kept for any length of time without change) to the condition of a stiff paste, with the aid of water slightly acidulated with sulphuric acid. When so reduced it must be applied immediately, as it hardens rapidly.

The Rotary Puddling Furnace.—According to a contemporary,* the commissioners sent to this country by the English Iron and Steel Institute, to examine and report upon the operation of Dank's rotary puddler, have made a report favorable to its adoption. In the telegram announcing this conclusion, they state that the furnace is successful, and in point of economy and in the quality of its work, satisfactory. In this report they even go beyond the limit assigned by the inventor, and recommend the construction of furnaces capable of puddling over 1,100 lbs. of iron, and assert that this large mass can be hammered or squeezed into a single ball. The general introduction of the machine puddler will necessitate a complete reconstruction of forges, since it requires that the appliances for hammering and rolling the puddled bloom shall be on a much larger scale than in the ordinary plan of operating, and the adoption of these changes will be a handsome tribute to the merits of the invention.

* Iron and Coal Trades Review.

Copying Drawings by Electricity.—An ingenious method of rapidly copying drawings or engravings is suggested by M. Chanderay,* who uses the induction coil for this purpose. The method adopted for this purpose by draughtsmen usually consists in puncturing holes through the design and thus obtaining an outline, which is subsequently transferred by sifting plumbago or other powder through the holes; a very laborious task where the drawing is large or has much detail.

In the plan proposed, a table covered with tin foil is connected with the negative pole of the inductorium, and on it is placed as many sheets of paper as the spark will penetrate. A metal bar, insulated with gutta percha, serves as the positive pole, and as a pencil for copying the tracings. This point is moved about on the outline of the engraving, and sparks pass through the paper to the tin sheet underlying it every time connection is made, puncturing four holes through the tissue at each passage. It is said that but little skill is required to guide the pencil, as the ink tracings, being good conductors, carry the pencil easily along.

Fog Signals.—C. S. Larned suggests the importance of creating a system of notes, to represent a small dictionary of words, with the fog whistle, by means of which captains of vessels may speak to each other at a distance through a dense fog.

There can be no doubt of the great advantage to be derived by this simple suggestion; its practicability seems to be attended with little difficulty, and if introduced by general consent, it might serve the purpose, in many cases, of saving both life and property, besides curtailing the expenses of many vessels in saving of time; by giving information to masters of vessels of their position, and warning them of danger.

The Planotype.—A contemporary describes a method of obtaining printing surfaces, to which the above name is attached.† The design to be engraved is transferred to a block of lime tree wood, which is then placed in a machine having somewhat the appearance of a sewing machine; but instead of the needle, we find a steel pin (the shape of which varies considerably according to the nature of the work), kept red hot by a gas jet. By means of this contrivance, the design is gradually burnt into the wood. Figures or letters of refer-

* Quart. Journ. of Science, xxxiii. 128.

† The Engineer, xxxiii. 14, from Dingler's Journal.

ence are impressed by means of suitable cut punches. When the design has been completely burnt into the wood, a cast is taken in type metal directly from the block. This cast, we are informed, may be used for printing from, without any additional preparation, precisely like a stereotype plate. It is stated that the wood does not suffer in the slightest degree from the heat of the molten metal, and that the finest detail may be reproduced.

Sodium as an Explosive Agent.—Since writing the former item upon the application of sodium as an explosive, we have received from Prof. Henry Wurtz, of New York, some additional information upon the subject, which is quite interesting, as being the record of the earliest experiments in this direction.

It appears from this, that the device found most effective for practical purposes by Prof. W., consisted in the use of an alloy of potassium and sodium, which is liquid at ordinary temperatures, prepared by the original method of Gay-Lussac and Thenard.

When this liquid alloy is brought into contact with any liquid of which oxygen is a constituent—as water—its decomposing action is far more rapid and energetic than that of the solid metals; so much more energetic, indeed, as to admit of no comparison. This increase in energy is precisely what might be anticipated, since the perfect intermingling of two liquid reagents would greatly facilitate the decomposition; producing a much more intensified action in a given period of time, than with the employment of the solid metal, as described in the former notice.

We are informed, by the same chemist, that he has substituted nitric acid and other substances, rich in oxygen, for water, and with increased effects.

The detail of these experiments was called forth by the recent labor of Springmühl, whose plan was described in our former notice. It would seem, from what has just preceded, that the work of Prof. Wurtz in this direction was far more exhaustive than that of Springmühl, who, to judge from his results, seems not to have been aware of the existence of these earlier experiments.

The amount of power at disposal in the plan under discussion is unlimited enough to satisfy the most exacting, and, in relation to the experiments made with it, it may be remarked that while the ultimate success or failure of the system in practice may be decided by practical considerations which have not yet entered into the dis-

cussion, and which cannot be predicted, the objection named in the previous article—that of wastefulness—is in a great measure obviated by the proposition of Prof. Wurtz to use both reagents in a liquid form.

A Method for Filling Barometer Tubes.—Mr. H. Wild,* after calling attention to the inconveniences and the danger of breaking barometer tubes attendant upon the method usually employed, namely, that of boiling the mercury in the tube, to insure a perfect vacuum, suggests a plan of his own, which is intended to obviate these objections.

A doubly tubulated spherical vessel is connected on one side with the tube to be filled, and on the other, first with a drying tube, and further on with an air-pump.

The spherical vessel is filled partly with the mercury, and the air is successively exhausted and admitted in this and in the tube, in order that the air within the apparatus shall be made perfectly dry by the action of the drying tube. When this is accomplished, a vacuum is produced by the pump, and the tubulated vessel tilted so that the metal may run gently into the barometer tube.

The remaining part of the operation will need no explanation. The author declares that he has operated frequently according to the plan he describes without having in a single instance either broken a tube or failed of success.

The Weather-Waste of Coal.—Dr. Varrentrapp has made this the subject of an investigation, and as a result states that the amount of loss suffered by coal from exposure to weather is considerable, far greater, indeed, than is generally known.

The results of his analyses show in some cases a total loss in weight of a specimen, from this cause, amounting to 33·08 per ct., while its deterioration in quality for purposes of fuel or gas-making reached a still higher figure.

This change consists in a slow combustion, in which the volatile constituents—which are most valuable combustible elements—are gradually eliminated, while the relative proportions of carbon, ash and sulphur are comparatively augmented.

It might be expected, now that the nature of this change is indicated, that anthracite (which has already gone through a very similar process in becoming what it is, by the loss of its bituminous mat-

* Pogg. Annalen cxliv, 137.

ter) should suffer least of all coals from this action, and the result of analysis shows this to be the case. The density and compactness of this variety, aside from its chemical character, protect it in no inconsiderable degree.

The Cannel coals rank next in their power to resist deterioration from this source; while the bituminous varieties are the most susceptible.

The experiments of Dr. Varrentrapp are of such direct and practical importance that all who are engaged in the mining, transportation, storage or consumption of coal can study them with profit.

It appears, from accurate tests of a number of samples before and after exposure, that all the valuable properties of the coal had deteriorated.

The coking quality of the weathered coal diminishes with its gas-yielding quality, the author informing us that a sample of coal yielding, when freshly mined, a firm coherent coke, after eleven days' exposure, yielded a coke of no coherence, and in all the samples tested the rule was absolute that the longer the coal had been exposed the greater was the inferiority in the quality of the coke it produced.

The gas-yielding quality decreased in one instance 45 per ct., and the heating power 47 per ct.; while the same sample under cover lost in the same time but 24 per ct. for gas purposes, and 12 per ct. for fuel.

These experiments go far to explain the almost universal inferiority of the slack or waste coals in heating power when prepared for burning, even though some combustible material like pitch or tar is used in their cementation. It indicates, too, the imperative necessity of keeping coals amply protected from the deteriorating action of the air and moisture by keeping them constantly dry and under cover.

The Mechanical Effect of Magnetization.—Prof. Tyndall, in a recent lecture, describes an interesting experiment, which may perhaps be new to some of our readers, in the following terms: "The effect which I wish to make manifest is this: at the moment when the current passes through the coil surrounding the electro-magnet a clink is heard emanating from the body of the iron, and at the same moment the current ceases a clink is also heard. In fact, the acts of magnetization and demagnetization so stir the particles of the magnetized body that they can stir the air and send sonorous impulses to our auditory nerves.

"The sounds occur at the moment of magnetization and at the moment when magnetization ceases; hence, if a means be devised of making and breaking in quick succession the circuit through which the current flows, we shall obtain an equally quick succession of sounds."

The lecturer then describes the contact breaker, and the position of the bar upon the bridges of a monochord, and continues: "The current is now active, and every individual present hears something between a dry crackle and a musical sound issuing from the bar in consequence of its successive magnetization and demagnetization."

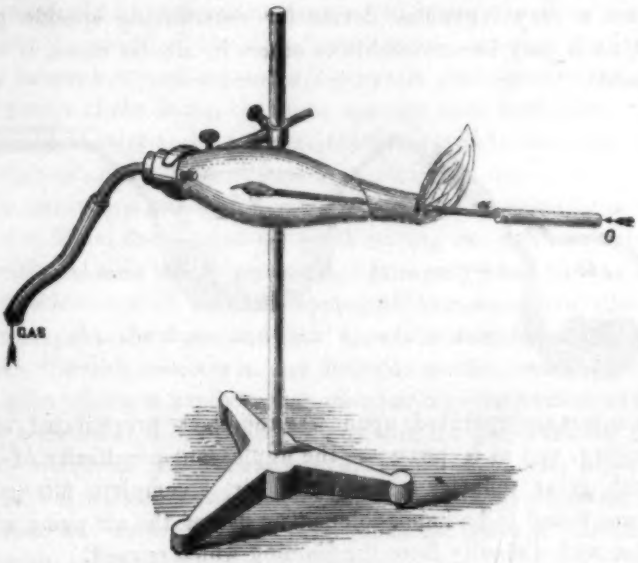
An Electrical Phenomenon.—Prof. S. H. Lockett relates the following observation in a letter from Niagara Falls: "While crossing the new suspension bridge, I had occasion, while conversing with a friend, to point towards the falls with my walking cane. As I did so, I heard distinctly at the end of my cane a buzzing noise. Repeating the experiment, the same noise was heard. I stopped several passers and tried their canes with the same result, except in the case of one which lacked a ferule. I immediately supposed this might be an electrical phenomenon, and set to work to test the correctness of this supposition. I took a key, and held it at arm's length towards the falls, and heard the same sound. Finally, at dark, I returned to the bridge, and pointing my cane, had the satisfaction of seeing a clear, beautiful electric brush on its end.

The best point to observe this interesting phenomenon is in the middle of the bridge, and the cane must be held at arm's length, so that its end may be at some distance from any part of the bridge. The success of the experiment depends a good deal on the direction of the wind, and the amount of vapor blown over the bridge." * *

India-Rubber Tubes and Gas.—We find in a contemporary* a description of a simple experiment showing the permeability of india-rubber to gases. A vessel is constructed with an india-rubber diaphragm, upon one side of which hydrogen is confined, and upon the other, air. In 28 days, 22·6 per cent. of hydrogen was found to have escaped into the air chamber, while 5·9 per cent. of air had entered. This was with vulcanized rubber; when pure rubber was used the diffusion was nine times greater.

* Journal de l'Eclairage du Gaz

A Lecture Experiment.—M. Ballo describes the accompanying arrangement by which the singing of reciprocal flames can be effected.*

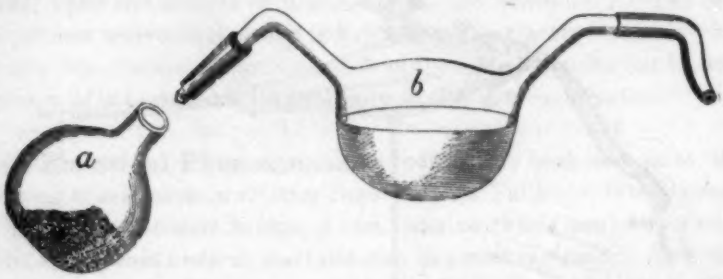


A glass cylinder, such as is used in the petroleum lamp, is attached upon a retort stand at very slight angle from the horizontal position. To one end is fitted a perforated cork, through which a glass tube supplies burning gas. The lower end is open, and protected from breakage by a fold of sheet iron. Oxygen is supplied at tbe open end by a straight tube drawn out to a fine point. The cylinder is first filled with burning gas and ignited at the lower end; the oxygen tube is then passed into the centre of the cylinder. In passing through the flame it is ignited, and, under these circumstances, produces a singing flame, very similar to that produced by hydrogen flame burned within a tall tube. By using air, the same result may be produced as with oxygen, the cylinder simply requiring to be larger. If the tube supplying the burning gas is in the centre of the cork, the flame will only be set in vibration when in the axis of the cylinder; nearer to the walls, it becomes slightly elongated but emits no sounds.

The effect, we are told, is not easy to be obtained, and a few trials are necessary to properly regulate the flow of the gases for the best results.

* Ber. d. Deutsch. Chem. Gesel., iv, 907.

Apparatus for determining Specific Gravity.—In an article* upon the occurrence of a new mineral in California, and which, in its thoroughness, may serve as a model investigation, Dr. G. E. Moore suggests a very ingenious device for determining specific gravity, which, as it may be serviceable to others in similar cases, is here reproduced.



The substance operated upon was the black precipitated sulphide of mercury, and as it possesses the unpleasant peculiarity of retaining with great tenacity a coating of air, a complete mixture with water was found to be impossible. The use of the air pump was also attended with difficulty from the foaming which ensued.

To meet the difficulty, the device shown in the accompanying figure was contrived. This consists of the ordinary specific gravity flask *a* which is connected with the Bunsen pump by means of the bulbed tube *b*, whose middle part had been widened out into a bulb of equal capacity with the flask, the communications between the bulb tube, which is filled to about three-fourths with water, and the flask being made air-tight by a moist rubber collar. As soon as the manometer of the air pump indicates the maximum of rarifaction, the apparatus is inclined, whereby the water runs gently from the bulb into the flask, penetrating every pore of the mass without forming a particle of scum.

A Method of observing Vibrating Flames.†—A contemporary gives a description of a simple apparatus for observing the phenomena of vibrating or sounding flames.

A disk of white card board is constructed with oblong apertures in a radial direction; this is set upon a spindle so as to admit of rotation at the requisite speed.

* Jour. für Praktische Chemie. n. f.

† Quarterly Journal of Science, xxxiii, 123.

To examine the flame of a gas light, for instance (the flame being protected by a glass tube from the disturbing effects of air currents), place the disk in front of the light, so that the eye can see the light through each slit as it comes to the vertical position.

If now, the speed of the disks' rotation, is such that the interval of time between two slits passing the eye is just equal to the period of a vibration of the flame, the flame appears to be motionless; but if this velocity of rotation be reduced, the flame will be observed to pass slowly through its changes of form.

If the interval is one-half, or one-third of the period of the vibration of the flame, the illusion of a disk having two or three times the number of real slits will be produced. It is only when the periods of flame-vibration and of the over lapping of two successive slits coincide in time, that the flame and disk appear motionless; when this is otherwise, the disk revolves in one direction or the other.

This plan affords a ready means of counting the number of vibrations of a flame, and by substituting a wire for the vibrating flame, the spiral course of the undulations produced in it may likewise be observed. Mr. Chas. Watson, who has described the experiment, has made some very accurate observations upon the times of vibrations of flame within tubes of different dimensions.

The Gases Occluded in Coal.—Dr. E. Mayer has recently examined some German coals, in order to determine the character of the gases absorbed in them, and, as the result of one analysis, which may serve as a fair sample, he found the following constituents: carbonic acid, 16·9; marsh gas, 20·4; nitrogen, 53 3; oxygen, 1·7; heavy carburetted hydrogens, 7·7 per cent. The large proportion of nitrogen, and the small quantity of oxygen, deserve especial notice. The coal experimented upon had been for some time in contact with the air.

A Delicate Test for Manganese.—Dr. Böttger* directs a few grammes of pure chlorate of potassa to be fused in a test-tube, and while fused a minute quantity of the material suspected of containing manganese to be dropped into it. The presence of a minute trace of this substance will, it is asserted, cause the fused mass to assume a more or less decided peach-blossom red color. It may thus be detected in wood, human hair, (especially if reddish), coal, minerals, etc.

* Polytech. Notiz-Blatt.

New Method of Preparing Supersaturated Solutions.—L. C. de Coppet* announces that by using the anhydrous salts in the preparation of these solutions for lecture or other purposes, they can be prepared with much less trouble than by the old plan of dissolving the crystallized and hydrated salts with the aid of heat.

The author employs the anhydrous sulphate of soda or of magnesia, the dry carbonate of soda, &c., and brings small quantities of them at a time into cold water, and is thus enabled to dissolve much more of the salts than can be accomplished at the same temperature with the hydrated bodies. Of sulphate of soda he asserts that five times as much can thus be obtained in solution as of the crystallized material ($Na_2SO_4 10H_2O$), and in all cases the introduction of a small crystal of the substance causes the solutions at once to crystallize.

New Mode of Preparing Oxygen.†—Mr. Mallet proposes to utilize the property which the subchloride of copper possesses, of absorbing atmospheric oxygen, and liberating the same when heated to about 400 F., in the manufacture of oxygen on the commercial scale.

This material, when moistened and exposed to the air, absorbs oxygen, forming an oxychloride. When this is heated, water is first liberated, and upon this the oxygen, leaving the subchloride behind.

This process may, according to the originator of the plan, be repeated as often as desired. One hundred (100) lbs. of the material, it is said, will furnish nearly fifty (50) cubic feet of oxygen at each operation.

New Use for Paraffin.—Dr. Vohl announces that, mixed with benzole or Canada balsam, paraffin affords a much superior glazing for frescoes than soluble glass. By covering the interior of wine casks with a film of pure white paraffin poured in melted, he has effectually prevented the spoiling of the wine, or its evaporation through the wood.

* Comptes Rendus, Dec. 4, 1871.

† Dingler's Jour., cc, 466.

Civil and Mechanical Engineering.

EXPERIMENTAL STEAM BOILER EXPLOSIONS.

By Professor R. H. Thurston.

The public, quite as much as professional engineers, have, from the earliest period in the history of the application of steam to useful purposes, felt a perfectly justifiable distrust of the steam boiler, whatever its form.

Indeed, the greater our familiarity with that powerful instrument, the more thoroughly do we appreciate the danger which attends its use, and those of the profession who have ever had charge of the machinery of a steam vessel, need not be reminded of the unceasing sense of anxiety and responsibility that, in most cases, has probably oppressed them by day and by night, when steaming, even where they have felt the greatest confidence in the intelligence and zeal of those to whom they have entrusted the care of the boilers.

Such terrible disasters as that which occurred on the *Westfield* last summer, and the epidemic of explosions that have signalized the last few months, have thoroughly re-awakened and intensified the apprehensions so universally felt.

It is to be hoped that a useful result may be a more earnest and intelligent investigation of the subject, and such additional legislation as may make the system of governmental inspection far more efficient than it is at present in the prevention of dangerous explosions.

During a few years past a number of accomplished engineers have been called, by the character of their duties, to investigate the circumstances attending nearly every case of steam boiler explosion in Great Britain, and recently many cases in the United States have been examined with similar care and skill.

A committee of the most experienced and talented among British engineers has also recently given attention to the same subject, with the object of determining what legislation should be recommended, and how far legislation may be expected to remedy this apparently rapidly increasing cause of danger to the public.

The very considerable amount of information thus obtained has been extremely useful in dispelling many of the strange superstitions

and extraordinary theories, of which both ignorance and intelligent but misdirected ingenuity have been wonderfully prolific. The conclusion which has been arrived at, after the examination of many hundreds of cases of accidental steam boiler explosion, is that such so-called accidents are the result of neglect or ignorance, and are never to be attributed to causes which are not, or may not be, easily understood by persons of ordinary intelligence. It is believed that most of these causes are now understood, that they are few in number and are readily controlled by the exercise of intelligence and vigilance.

A *direct proof* of these deductions is, however, still needed, and this can only be obtained by a series of experiments made with direct reference to the production of such proof. Such experiments would be the exploding of boilers under, as nearly as possible, the conditions observed in practice and carefully studying the influence that variations of those conditions may have upon the nature and intensity of the resulting effects.

Comparatively little has yet been done in this direction. More than thirty-five years ago, a committee of the Franklin Institute made a series of experiments of such extent and accuracy that the republication of their reports, and their circulation among engineers, would to-day be a public benefaction.* Their reports, together with the paper of F. A. Paget, on the "Wear and Tear of Steam Boilers,"† and the little book of E. B. Martin‡ on explosions, should be in the library of every engineer.

The experiments of the committee of the Franklin Institute were made upon a small scale, and upon constructions quite different in form from most steam boilers, and, although the information obtained was invaluable, it still remained desirable to repeat their experiments and to make other investigations with boilers of full size, such as are used in steamers, on our railroads, and in our manufactories.

The only experiments of this kind ever attempted were probably those referred to by the President of the Franklin Institute, in his letter published in the concluding number of the last volume of this *Journal.*

It was intended to defer an account of their origin and progress until the completion of the series, but as cold weather has interrupted

* *Vide* Journal Franklin Institute, 1836, Vol. XVII.

† Ibid., 1865, Vol. I.

‡ Records of Steam Boiler Explosions; E. B. Martin: London: E. & F. N. Spon, 1871.

operations, and as the work will not be resumed until spring, it is considered advisable to describe the experiments already made.

These experiments were projected and conducted by Mr. Francis B. Stevens, of Hoboken. They were planned several months ago, and at the request of Mr. S. the United Railroad Companies of New Jersey, with an intelligent appreciation of the importance of such an investigation, both to themselves and to the public, appropriated the sum of ten thousand dollars to enable Mr. Stevens to enter upon a preliminary series of experiments. They, at the same time, invited other railroads and owners of steam boilers to coöperate with them, and offered the use of their shops for any work that might be considered necessary or desirable during the progress of the work.

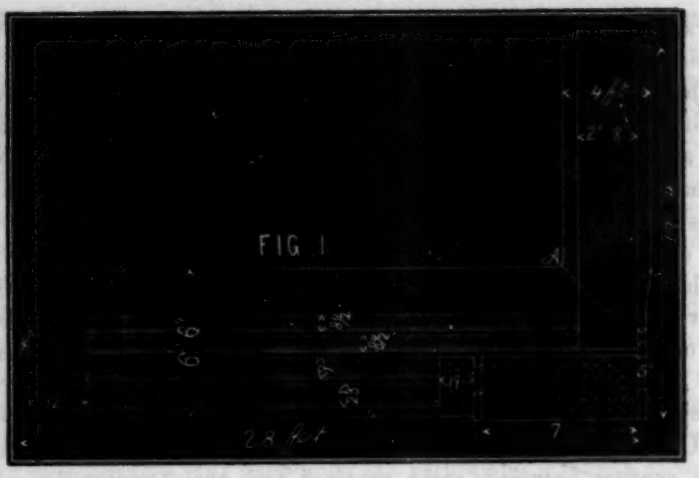
Several old boilers had recently been taken out of the steamers of the United Companies. These were subjected to hydrostatic pressure, until rupture occurred, were repaired and again ruptured several times each, thus detecting and strengthening their weakest spots, and finally leaving them much stronger than when taken from the boats. The points at which fracture occurred and the character of the break were noted carefully at each trial.

After the weak spots had thus been felt out and strengthened, the boilers were taken, with the permission of the War Department, to the U. S. reservation at Sandy Hook, at the entrance to New York Harbor, and were there set up in a large enclosure which had been prepared to receive them. This work was one of great difficulty, but it was skilfully performed, and was accomplished without accident, and the four old steamboat boilers above referred to, together with five new boilers built for the occasion, were placed in their respective positions without having been in any way injured.

Finally, on the 22d and 23d of November, the experiments to be described were made. A large party of gentlemen, many of whom were professional engineers, and all of whom were deeply interested in the subject, were invited to attend, by Mr. S., on behalf of the United Railroad Companies of New Jersey.

The first boiler attacked was an ordinary "single return flue boiler." Figure 1.

The cylindrical portion of the shell was 6 feet 6 inches diameter, 20 feet 4 inches long, and of iron a full quarter inch thick. The total length of the boiler was 28 feet, the steam chimney was 4 feet diameter, 10½ feet high, and its flue was 32 inches diameter. The two furnaces were 7 feet long, with flat arches. There were ten lower



flues, two of 16 and eight of 9 inches diameter, and all were 15 feet 9 inches long: there were twelve upper flues, 8½ inches in diameter, and 22 feet long. The total grate surface was 38½ square feet, heating surface 1350 square feet. The water spaces were 4 inches wide, and the flat surfaces were stayed by screw stay-bolts at intervals of 7 inches.

This boiler was one of a pair built by Fletcher, Harrison & Co., of New York, for the steamer *Joseph Belknap*, in 1858, and, with its fellow, which was also on the ground, had seen 13 years of service. The last Inspector's certificate had allowed 40 pounds of steam. The upper portion of the boiler, when inspected before the experiment, seemed to be in good order. The girth seams on the under side of the cylindrical portion had given way, and had all been patched before it was taken out of the boat. The water legs had been considerably corroded.

In September last, in presence of several gentlemen who had been invited to witness the test, this boiler had been subjected to hydrostatic pressure, giving way by the pulling through of stay-bolts at 66 pounds per square inch. It was repaired and, afterward, at Sandy Hook, was tested without fracture to 82 pounds, and still later bore a steam pressure of 60 pounds per square inch.

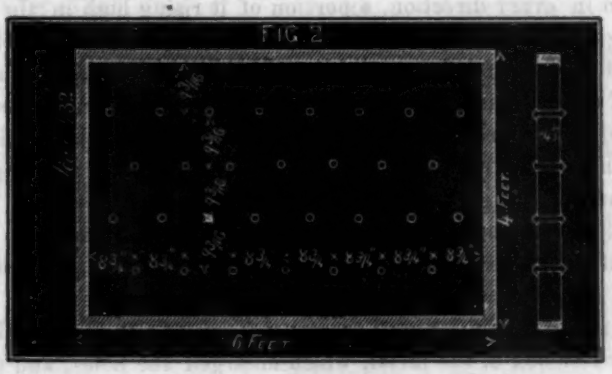
On its final trial, November 22d, a heavy wood fire was built in the furnaces, the water standing 12 inches deep over the flues, and, when steam began to rise above 50 pounds, the whole party retired to the gauges, which were placed about 250 feet from the enclosure, and

which had been there proved to give accurate indications. The notes of pressures and times were taken as follows:

Time.	Pressure.	Time.	Pressure.	Time.	Pressure.	Time.	Pressure.
2.00 P.M.	58 lbs.	2.15 PM.	87 lbs.	2.25 P.M.	91½ lbs.	2.40 P.M.	91½ lbs.
2.05 "	68 "	2.20 "	91½ "	2.30 "	91 "	2·45 "	91 "
2.10 "	78 "	2.23 "	93 "	2.35 "	91½ "	2.50 "	90 "

The pressure rose rapidly until it reached about 90 pounds,* when leaks began to appear in all parts of the boiler, and at 93 pounds a rent at (A, Fig. 1) the lower part of the steam chimney where it joins the shell becoming quite considerable, and other leaks of less extent enlarging, the steam passed off more rapidly than it was formed. The pressure then slowly diminishing, the workmen extinguished the fires by throwing earth upon them, and the experiment thus ended.

The second experiment was made with a small boiler (Figure 2),



which had been constructed to determine the probable strength of the stayed surface of the *Westfield's* boiler. It had the form of a square box, 6 feet long, 4 feet high, and 4 inches thick. Its sides were $\frac{5}{16}$ inch thick, of the Abbott Iron Company's "best flange fire-box" iron. The water space was $3\frac{3}{8}$ inches wide. The rivets along the edges were $\frac{3}{4}$ inch diameter, spaced 2 inches apart. The two sides were held together by screw stay-bolts, spaced $8\frac{3}{4}$ and $9\frac{3}{16}$ inches, and their ends were slightly riveted over, precisely copying the distribution and workmanship of that water leg of the *Westfield*, which was formed between the back connection and the back end of the boiler. It had

* The ultimate strength of this boiler, when new, was probably equal to about double this pressure.

been tested to 138 lbs. pressure. This slab was set in brickwork, about five-sixths of its capacity occupied by water, and fires built on both sides. Pressure rose as shown by the following extract from the note book of the writer :

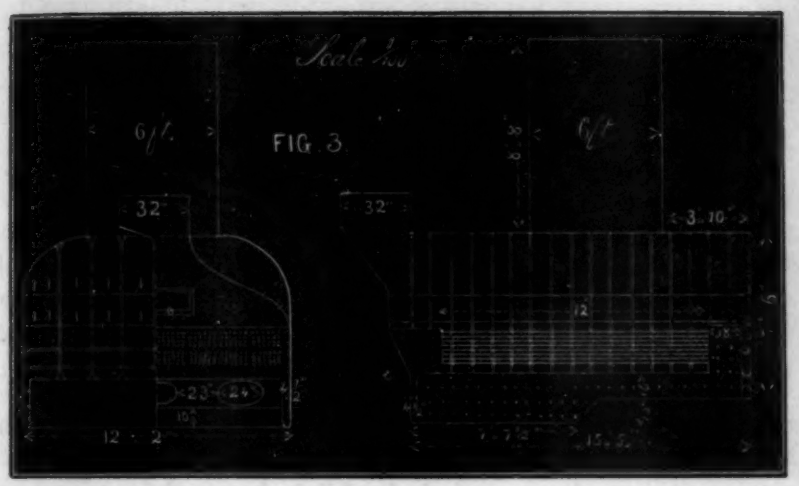
Time.	Pressure.	Time.	Pressure.	Time.	Pressure.	Time.	Pressure.
3.18 P.M.	0 lbs.	3.27 P.M.	18 lbs.	8.35 P.M.	49 lbs.	3.43 P.M.	94 lbs.
3.20 "	4 "	3.28 "	20 "	3.36 "	51 "	3.44 "	100 "
3.21 "	5 "	3.29 "	23 "	3.37 "	54 "	3.45 "	110 "
3.22 "	7 "	3.30 "	27 "	3.38 "	58 "	3.46 "	117 "
3.23 "	9 "	3.31 "	30 "	3.39 "	65 "	3.47 "	126 "
3.24 "	11 "	3.32 "	34 "	3.40 "	72 "	3.48 "	135 "
3.25 "	13 "	3.33 "	38 "	3.41 "	78 "	3.49 "	147 "
3.26 "	15 "	3.34 "	44 "	3.42 "	86 "	3.50 "	160 "
						3.51 "	165 "
						Exploded.	

At a pressure of slightly above 165, and probably at about 167 lbs., a violent explosion took place. The brickwork of the furnace was thrown in every direction, a portion of it rising high in the air and falling among the spectators near the gauges; the sides of the exploded vessel were thrown in opposite directions with immense force, one of them tearing down the high fence at one side of the enclosure, and falling at a considerable distance away in the adjacent field; the the other part struck one of the large boilers near it, cutting a large hole, and thence glanced off, falling a short distance beyond.

Both sides were stretched very considerably, assuming a dished form of 8 or 9 inches depth, and all of the stay-bolts drew out of the sheets without fracture and without even stripping the thread of either the external or the internal screw; this effect was due partly to the great extension of the metal, which enlarged the holes, and partly to a rolling out of the metal as the bolts drew from their sockets in the sheet.

Lines of uniform extension seemed to be indicated by a peculiar set of curved lines cutting the surface scale of oxide on the inner surface of each sheet, and resembling closely the lines of magnetic force called, by physicists, magnetic spectra. These curious markings surrounded all of the stay-bolt holes.

The third experiment took place on the 23d of November. The boiler selected on this occasion is shown in Figure 3. It was a "return tubular boiler," with no lower flues; the furnace and combustion chamber occupying the whole lower part. Its surface extended the whole width of the boiler, thus giving an immense crown sheet, which



was perfectly flat, and was braced to the shell by "crow-foot" braces whose rods were in section 2 inches by ½ inch, and spaced 12 inches lengthwise and 17 inches crosswise the boiler; each brace sustained an area of 204 square inches. The water legs were secured by stay-bolts of 1 inch diameter, spaced 12 inches by 8. The horizontal braces were spaced 28 inches by 12, and were 1⅛ inches diameter. The shell was of No. 3 iron, single riveted. There were 384 tubes, 2 inches diameter and 12 feet long. The steam drum was placed at the middle of the boiler, and was 6 feet diameter, and 8 feet 8 inches high.

This boiler was built in 1845, by T. F. Secor & Co., and had been at work *twenty-five years;* when taken out, the inspector's certificate allowed 30 lbs. of steam. In September it was subjected to hydrostatic pressure, which at 42 pounds broke a brace in the crown sheet, and at 60 pounds, 12 of the braces over the furnace gave way, and allowed so free an escape of water as to prevent the attainment of a higher pressure. The broken parts were carefully repaired, and the boiler again tested at Sandy Hook to 59 lbs., which was borne without injury, and afterward a steam pressure of 45 lbs. left it still uninjured. At the final experiment, the water level was raised to the height of 15 inches above the tubes, and it there remained to the end. The fire was built, as in the previous experiments, with as much wood as would burn freely in the furnace, and the record of pressures was as follows:

Time.	Pressure.	Time.	Pressure.	Time.	Pressure.
12.21 P.M.	29½ lbs.	12.27 P.M.	41 lbs.	12.32 P.M.	50 lbs., brace broke.
12 23 "	33½ "	12.29 "	44½ "	12.33 "	52 "
12.25 "	37½ "	12.31 "	48½ "	12.34 "	53½ " exploded.

When a pressure was reached of 50 pounds per square inch, a report was heard which was probably caused by the breaking of one or more braces, and at 53½ pounds, the boiler was seen to explode with terrible force. The whole of the enclosure was obscured by the vast masses of steam liberated; the air was dotted with the flying fragments, the largest of which—the steam drum—rising first to a height variously estimated at from 200 to 400 feet, fell at a distance of about 450 feet from its original position. The sound of the explosion resembled the report of a heavy cannon. The boiler was torn into many pieces, and comparatively few fell back upon their original position.

The same bulging of stay-bolted surfaces that was noticed in the preceding experiment was observed here, and the screw stay-bolts slipped out as before, without breaking and without stripping their threads. The braces were usually broken at the welds.

Having briefly described these experiments, it may be well to notice what bearing their results have upon existing beliefs, and how far they extend our knowledge of the causes and conditions of explosions.

In the first experiment, we probably have an illustration of by far the most usual behavior of steam boilers, when yielding to over-pressure. The pressure gradually rising, ruptured the boiler at its weakest point, which happened to be a spot of merely *local* weakness; the rent extended toward stronger portions, but soon became large enough to discharge the steam as rapidly as it was made. The strength of the metal in the direction of the line of fracture being sufficient to resist further extension at the maximum pressure attained, no greater injury was done. The spot being patched, the boiler is probably still capable of doing good service for a considerable length of time.

When boilers give way from excessive weakness or from over pressure, they very generally do so in the manner described. The explosion is the exceptional case, and the frequency with which old boilers "blow out" in every part, though usually about the stayed surfaces, and the apparent impunity with which they are kept at work after being frequently patched, has probably been the most in-

fluential cause of the existence of the belief, which is, unfortunately, widespread among engineers, that the mere pressure of steam cannot cause explosions, and that, if the boiler contains a sufficient quantity of water, it is perfectly safe, except against sundry mysterious forces, which are probably, like the fairies and ghouls of earlier times, existent only in the imaginations of those whom they terrify.

In the second and third experiments, we have illustrations of the comparatively rare cases in which explosions actually occur.

The second was a perfectly new construction, in which corrosion had not developed a point of great comparative weakness, and the edges yielding along the lines of rivetting on all sides simultaneously and very equally, the two halves were completely separated, and thrown far apart with all of the energy of unmistakeable explosion, although there was an ample supply of water, and the pressure did not exceed that frequently reached in locomotives and on the western rivers, and although the boiler itself was quite diminutive.

The circumstance of the drawing out of the stay-bolts without breaking and without stripping their threads, was one of the most interesting points of the experiment.

Constructing a formula upon the very probable hypothesis that this was an example of average American practice, we obtain for ordinary use $d = \frac{365\,t}{\sqrt{f\,\mathrm{P}}}$; where $d =$ the distance between staybolts, $t =$ the thickness of the plates, $\mathrm{P} =$ the pressure f and $=$ the factor of safety which certainly *ought, in no case, to be less than six.*

Also $\mathrm{P} = f\left(\frac{365\,t}{d}\right)^2$, the units of measure being lbs. and inches.

Fairbairn proved, by experiment, that the diameter of screwed stays should be double the thickness of the sheet, in order to make their tensile strength equal to the force that would draw them out of the sheets. To this should be added $\frac{1}{4}$ inch allowance for corrosion. These staybolts should have been $\frac{7}{8}$ inch in diameter, the $\frac{1}{4}$ inch excess of diameter being comparatively valueless.

The spacing of the staybolts, in a boiler of such workmanship, intended to carry 40 pounds of steam, and taking six as a factor of safety, should, however, have been $d = \frac{365 \times \frac{5}{16}}{\sqrt{6 \times 40}} = 7{\cdot}3 +$, or about $7\frac{1}{2}$ inches.

Fairbairn showed that properly rivetting over the ends, increased the strength of staybolts 14 *per cent.*

In the third experiment, as in the second, it is probable that the weakest part extended very uniformly over a large part of the boiler, either in lines of weakened metal, or over surfaces largely acted upon by corrosion. Immediately upon the giving way of its braces, fracture took place at once in many different parts.

In this example, the boiler had been standing a week with steam up, but with none blowing off, and feed being pumped in, unless to supply the insignificant waste from leakage. It was set on solid ground, and the water which it contained could not have been in the slightest degree agitated. It has been a question whether the water might not, under these circumstances, have become super-heated, as in the cases first noticed by M. Deluc, and since investigated by MM. Downy, Dufour and others, and whether the violence of this explosion may not have been largely due to such action.

When it is remembered, however, that those experimenters found it difficult to induce this condition in metal vessels with even minute quantities of water, and that the extent of this super-heating becomes quite small with very small quantities of the fluid, growing rapidly less as the bulk of water increases, it may be very much doubted whether it would be possible to obtain such a state in this case, where tons of water were contained in a rough metal vessel, and also where a circulation was constantly kept up by a fire at one end.

The quantity of heat thus stored up must have been very small, even if there were any such excess.

Were it known precisely to what height the steam drum, for example, was thrown in this case, it would be easy to determine with great certainty, whether the steam released at 53½ lbs. pressure was sufficient to produce the effects noted.

We have made such an estimate, but the data are too unreliable to admit of its publication, although it confirms our opinion that no super-heating of the water in the boilea took place.

We may conclude, then, from the result of Mr. Stevens' experiments:—

First, That "low water," although undoubtedly one cause, is not the only cause of violent explosions, as is so commonly supposed, but that a most violent explosion may occur with a boiler well supplied with water.

This was shown on a small scale by the experiments of the committee of the Franklin Institute above referred to.

Second, That what is generally considered a moderate steam pres-

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sure may produce the very violent explosion of a weak boiler, containing a large body of water, and having all its flues well covered.

This has never before, we believe, been directly proven by experiment.

Third, That a steam boiler may explode, under steam, at a pressure less than that which it had successfully withstood at the hydrostatic test.

The last boiler had been tested to 59 lbs., and afterward exploded at 53½ lbs. This fact, too, although frequently urged by some engineers, was generally disbelieved. It has now been directly proven.*

There can now be no excuse for the implicit confidence so generally felt in the use of the hydrostatic test, or for not at least combining with it, in every inspection, the use of the "hammer test" by experienced inspectors.

It may be finally remarked, that welded boiler braces, and screw stay-bolts which have not nuts at their end or are not well riveted over, should evidently be distrusted.

This extremely interesting and important series of experiments will be continued on the return of warm weather, and it is hoped that Congress may be induced to make provision for its extension. A very excellent report, made to the Secretary of the Navy, by Chief Engineers Isherwood, DeLuce and S. Albert, has been printed by Mr. Stevens, together with a memorial, asking Congress to take action in this matter, which is of such great importance to the public. These will be circulated among those who may be willing and able to aid in the plan proposed.

It is proposed by Mr. Stevens, in the experiments succeeding those now prepared, to determine the conditions of explosion with low water, to examine into the effect of opening the safety valve suddenly upon

* A number of instances of this kind, though not always producing an explosion, have been made known to the writer.

Two boilers at the Detroit Water Works, in 1859, after resisting the hydrostatic test of 200 lbs. with water, at a temperature of 100° Fahr., broke several braces each at 110 and 115 lbs. steam pressure respectively, when first tried under steam.

The boiler of the U. S. steamer Algonguin was tested with 150 lbs. cold water pressure, and broke a brace at 100 lbs. when tried with steam.

A similar case occurred in New York, a few years ago, and the boiler exploded with fatal results,

These accidents are probably caused by changes of form of the boiler, under varying temperature, which throw undue strain upon some one part, which may have already been nearly fractured.

an already heavily strained boiler, and to check those experiments that seem to prove explosions to occur from excessive pressure, by leading steam at high pressure into a comparatively weak boiler containing no water. It is intended to explore this wide field of research as thoroughly as available time and money will allow.

It is to be hoped that our wealthy railroad corporations and owners of steam vessels may see how deeply their own interests are involved in the prosecution of such researches, and that they, as well as the general government, may assist in continuing these investigations.

Stevens' Institute of Technology, Hoboken, N. J., Dec., 1871.

PROBLEM OF THE RAFTERS.

By De Volson Wood.

The sloping timbers at the ends of a roof truss are called rafters, whether the truss is a "King Post," a "Queen Post" or other form. When the load is applied at the joints of the truss, the solution seems to present little or no difficulty;—at least authors do not differ in their results. But when the load is uniformly distributed over the rafter, or is applied at points along the rafter, authors differ in their results, as may be seen by examining Trautwine's Engineer's Pocket Book, pp. 247–252. Mr. Trautwine gives his own solution, and refers to Rankine's Civil Engineering, p. 470, for the solution which is commonly given. I find, according to the solution given below, that the horizontal pressure at the upper end is the same as that given by Prof. Rankine, but the longitudinal compression along the rafter is not correctly given by any author so far, as I am acquainted with them.

In order to simplify the problem as much as possible, we will at first consider a single rafter supporting a single weight P, which is applied at any point. The lower end of the rafter, B, is held in the usual way by resting upon a support which sustains the vertical pressure, and by a tie rod which resists the horizontal push. The upper end is held by a horizontal force, which in any case is sufficient to hold the system in equilibrium.

In Fig 1 let

A B = the length of the rafter.

D = A E = the rise.

l = E B = the run of the rafter, or its horizontal projection.

$n\,l$ = B F = the horizontal distance of the point of application of the weight from B.

θ = the angle B C F = B A E.

P = the weight which is applied at C.
P_1 = the reaction of the support B.
H = the horizontal pressure at A.
H_1 = the horizontal pressure at B.

It is a principle of statics that the algebraic sum of the vertical components of all the forces in a system in equilibrium is zero,—and the same is true of all the horizontal components. Or, in this case, the sum of all the forces acting downwards, equals the sum of all those acting upward; and the sum of the horizontal forces pressing to the right equal those pressing towards the left. Hence

$$P = P_1, \text{ and}$$
$$H = H_1.$$

Taking the moments about B we have

$$H\,D = P\,n\,l$$
$$\therefore H = n\,P\,\frac{l}{D} = n\,P \text{ tang } \theta \quad . \quad . \quad . \quad (1)$$

Taking the moments about A, we have

$P_1\,l = H_1\,D + (1-n)\,P\,l$ or making $P = P_1$ we have

$P\,l = H_1\,D + (1-n)\,P\,l$

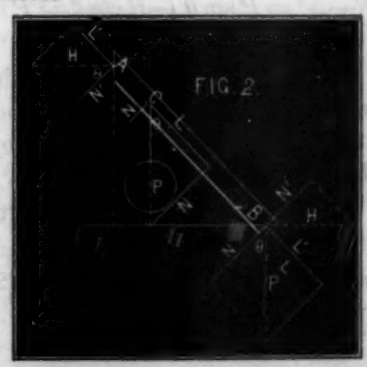
$$\therefore H_1 = n\,P\,\frac{l}{D} = n\,P \text{ tang } \theta \text{ as before;}$$

Or, assuming that $H_1 = H$ and we have

$P_1\,l = H\,D + (1-n)\,P\,l$, in which substitute the value of H from (1) and we have

$$P_1\,l = n\,P\,l + (1-n)\,P\,l$$
$$\therefore P_1 = P \text{ as before.}$$

Next find the compression along the rafter.



Instead of the single horizontal force at A, we may substitute two other forces such that the resultant of the two shall equal H. The two forces will evidently produce the same result as H. As we seek the longitudinal effect, let one of the components be taken in that direction and call it L^1. The other com-

ponent, to produce no longitudinal effect, must be perpendicular to the rafter. Call it N^1. These forces are shown in Fig. 2.

Hence, we immediately have

$$L^1 = H \sin\theta = n\,P \tan\theta \sin\theta = n\,P\,\frac{\sin^2\theta}{\cos\theta} \quad . \quad . \quad (2)$$

$$N^1 = H \cos\theta = n\,P \tan\theta \cos\theta = n\,P \sin\theta \quad . \quad . \quad (3)$$

The latter component N^1 produces only bending, and is resisted by a component of the applied weight, P. The former component produces compression only, and is the only compressive force between A and C. At C this force is increased by a component of the weight.

Let N = the normal component of P, and

L = the longitudinal component of P.

Then $N = P \sin\theta$, and . . . . . (4)

$$L = P\cos\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Between C and B the total longitudinal compression is

$$L^1 + L = n\,P\,\frac{\sin^2\theta}{\cos\theta} + P\cos\theta = \frac{P}{\cos\theta}\left[n\sin^2\theta + \cos^2\theta\right] \quad (6)$$

As a check upon the work we may find the reactions of the forces at B.

For H we have the two components

$$L^1 = H\sin\theta.$$
$$N^1 = H\cos\theta.$$

And for P we have

$$L = P\cos\theta.$$
$$N = P\sin\theta.$$

Hence, the resultant longitudinal pressure is

$$L + L^1 = P\cos\theta + H\sin\theta = \frac{P}{\cos\theta}\left[n\sin^2\theta + \cos^2\theta\right] \text{ as before.}$$

The resultant normal pressure is

$$N - N^1 = P\sin\theta - H\cos\theta = P\sin\theta - n\,P\sin\theta = (1-n)\,P\sin\theta \quad (7)$$

Adding (8) and (6), we have

$$P\sin\theta,$$

which is the same as (4), as it should be, since the normal pressures at the ends should be equal and opposite to the normal component of the applied weight.

DISCUSSION.

1. If the rafter is vertical, $\theta = 0$, and the compression on the upper part, between A and C is, from (2)

$$L^1 = 0,$$

and the compression on the lower part, between C and B, from (6), is

$$L = P$$

and the horizontal thrust is, from (1), equal to zero.

2. If the rafter has any inclination and P is placed at A, n is equal to 1 in all the equations, and (1) gives

$$H = P \text{ tang } \theta,$$

which is the value given for this case by all writers. Equation (2) gives

$$L^1 = P \text{ tang } \theta \sin \theta,$$

but, as in this case, C falls upon A, and hence A C = 0, this merely gives the component of H in that direction and does not give the compression upon any finite length of the rafter. Equation (6) gives

$$L + L^1 = \frac{P}{\cos \theta} = P \sec \theta,$$

which is also the value given by all writers for the compression upon a brace where the total load is placed at the upper end of the brace.

3. If P is placed at the lower end of the beam, n = 0, and equations (1), (2) and (6) give

$$H = 0,$$
$$L^1 = 0,$$
$$L + L^1 = P \cos \theta;$$

the last of which is the longitudinal component of P, but as in this case C falls on B the resultant compression does not apply to any finite portion of the rafter.

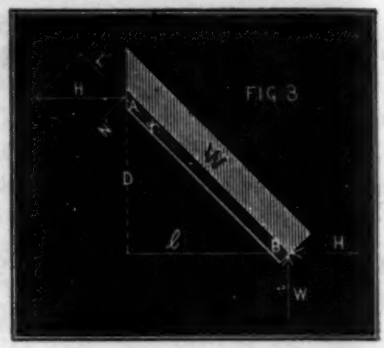
4. Let the rafter be horizontal, then $\theta = 90°$, and equations (1), (2), and (6) become

$$H = \infty$$
$$L^1 = \infty$$
$$L + L^1 = 0 + \infty$$

5. If P be applied at the middle, $n = \frac{1}{2}$, and we have

$$H = \tfrac{1}{2} P \text{ tang } \theta$$
$$L^1 = \tfrac{1}{2} P \text{ tang } \theta \sin \theta$$
$$L + L^1 = \frac{P}{\cos \theta}\left[\tfrac{1}{2} \sin^2 \theta + \cos^2 \theta\right]$$

By supposing that P is applied at different points, and taking the sum of the results, we may find the effect of several weights applied simultaneously.



Now suppose that the rafter is uniformly loaded over its whole length, and let n = the load on a foot of length of the rafter, and W = the total load.

(Those who compare this solution with Rankine's—*Civil Engineering*, p. 470—will observe that he calls W the load on two rafters, and hence $\frac{1}{2}$ W is the load on one rafter.) Taking the moments about B and observing that the lever arm of W is $\frac{1}{2}$ l, and we have

$$H D = W \tfrac{1}{2} l \quad \therefore \quad H = \tfrac{1}{2} W \frac{l}{D} = \tfrac{1}{2} W \text{ tang } \theta \quad . \quad . \quad (8)$$

If x be any distance from A measured along the rafter, $w x$ will be the load on that length, and the longitudinal component of it will be, according to equation (5),

$$L = w x \cos \theta$$

and the longitudinal component of H is,

$$L^1 = \text{H} \sin \theta.$$

Hence the total compression at any section whose distance is x from A, is

$$L + L^1 = w x \cos \theta + H \sin \theta = w x \cos \theta + \tfrac{1}{2} W \text{ tang } \theta \sin \theta, \quad (10)$$

DISCUSSION.

1. At the lower end x = A B, and $w x$ becomes w A B = W, and hence *the compression at the lower end is*

$$W \cos \theta + \tfrac{1}{2} W \text{ tang } \theta \sin \theta = \frac{W}{2 \cos \theta} \left[2 \cos^2 \theta + \sin^2 \theta \right] \quad (11)$$

$$= \frac{W}{2 \cos \theta} \left[1 + \cos^2 \theta \right]$$

2. *At the upper end* x = o and (10) becomes

$$\tfrac{1}{2} W \text{ tang } \theta \sin \theta = \frac{W}{2 \cos \theta} \sin^2 \theta = \tfrac{1}{2} W \sec \theta \sin^2 \theta \quad . \quad (12)$$

3. If the rafter is vertical, θ = o and (10) becomes

$$L + L^1 = w x,$$

which at the upper end is zero for x = o, as it should, and at the lower end it becomes

$$w x \text{ A B} = W$$

as it should since the total load rests upon it.

4. At the middle $x = \frac{1}{2} l$, and (10) becomes

$$L + L^1 = \tfrac{1}{2} W [\cos \theta + \text{tang } \theta \sin \theta] = \frac{W}{2 \cos \theta} = \tfrac{1}{2} W \sec \theta \quad (13)$$

5. If the rafter is horizontal $\theta = 90°$, and (10) becomes

$$L + L^1 = 0 + \infty,$$

from which it appears that the compression due directly to the loading is zero; and that due to the resultant horizontal thrust is ∞, as it should be in order to support the weight.

Having deduced, as we believe, the correct formulæ for this case, it will be easy to test the correctness of the formulæ which are deduced by others.

Prof. Rankine, in the reference made above, leaves us to infer that the longitudinal compression will be uniform throughout, and finds its value by assuming that one half the load is supported at each end of the rafter. In this way we readily find that the strain would be

$$\tfrac{1}{2} W \sec \theta$$

which compared with (12), (13) and (11) shows that it is too great at the upper end, correct at the middle, and too small at the lower end. If the rafter is vertical the above expression gives $\frac{1}{2} W$ for the compression, whereas it should be zero, and at the lower end it is only half enough. The horizontal thrust at the upper end, by this method, is $\frac{1}{2} W$ tang θ which is the same equation (8).

Trautwine considers that the total pressure at the foot of the rafter is a vertical force producing compression. This resolved horizontally and obliquely gives

$$H = W \text{ tang } \theta$$
$$L + L^1 = W \sec \theta$$

both of which are double the value given by Prof. Rankine and the former is double the correct value.

This method at first appears so plausible, that it may be advisable to show its fallacy by an illustration.

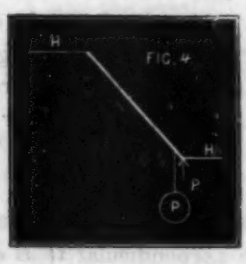
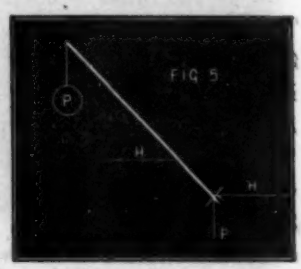


FIG. 4.

If P is very near the lower end of the rafter, as in Fig. 4, it is evident that H will be small, while the reaction is still equal to P; and if the weight P is exactly over the support it will develop no horizontal thrust, but in all these cases, according to Trautwine's formula, the horizontal thrust is the same. The longitudinal compression due to *P directly* is constant for all positions of P for the same inclination of the raf-

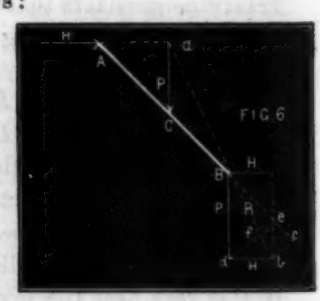
ter, and is $P \cos \theta$; but the compression due to H is dependent upon the position of P, being small when P is near B. Observe that P may be constant and H may have all possible values depending upon the position of P.



If P is considerably above H, as in Fig. 5, the lower end still sustains P and the horizontal thrust greatly exceeds that in Fig. 4. The compression in this case due to P is the same as in the preceding case, while that due to H greatly exceeds that in the preceding case.

It is worthy of note that the strains in this rafter are independent of the inclination of the rafter, brace, or beam, which holds its upper end in any practiced case, *provided* that the two *rest against* each other.

But these illustrations only show the general fact by passing so near the limits of the problem as to make the result appear absurd, but I think they will make the following solution more easily understood. The seat of Mr. Trautwine's error consists in assuming that *the resultant of the two forces at the foot of the rafter is in the direction of the rafter.* This hypothesis is true only when the weight rests upon the upper end of the rafter. The true direction of the resultant may be found geometrically as follows:



Let P, Fig. 6, be applied at any point, then since H and P are in equilibrium about B, the resultant of P and H must pass through that point. It must also pass through the point a where their line of directions meet. Hence a B is the direction of the resultant. If this resultant be resolved parallel to and perpendicular to the direction of the rafter, the former will give the compression between C and B, due to H and P. We have from equation (1) $H = n\,P$ tang θ, hence the resultant,

$$R = \sqrt{H^2 + P^2} = P\sqrt{n^2 \tan^2 \theta + 1} = \frac{P}{\cos \theta}\sqrt{n^2 \sin^2 \theta + \cos^2 \theta}$$

To resolve this multiply it by the cos of $b\,B\,c$. Erect $d\,e$ and $b\,e$ perpendicular to $B\,c$, and $b\,f$ perpendicular to $d\,e$. Call $B\,d = 1$, then from,

$$d\,b = \text{n tang } \theta,$$
$$d\,B\,c = \theta = f\,d\,b,$$

$$\therefore b\,B = \sqrt{\text{n}^2 \text{ tang}^2\ \theta + 1}$$
$$B\,e = \cos\,\theta, \text{ and}$$
$$f\,b = \text{e c} = \text{n tang } \theta \sin\,\theta.$$
$$\therefore B\,c = n \text{ tang } \theta \sin\,\theta + \cos\,\theta, \text{ and}$$

$$\cos\,b\,B\,c = \frac{n \text{ tang } \theta \sin\,\theta + \cos\,\theta}{\sqrt{\text{n}^2 \text{ tang}^2\ \theta + 1}} = \frac{n \sin^2\,\theta + \cos^2\theta}{\sqrt{n^2 \sin^2\,\theta + \cos^2\,\theta}}$$

The last expression is found by multiplying the terms of the preceding fraction by cos θ.

The total compressive force is found by multiplying the value of R given above, by the cos of b B c as just found. This gives

$$\text{Compression} = \frac{P}{\cos\,\theta}\sqrt{n^2 \sin^2 + \cos^2} \times \sqrt{\frac{n \sin^2\,\theta + \cos^2\,\theta}{n^2 \sin^2\,\theta + \cos^2\,\theta}}$$

$$= \frac{P}{\cos\,\theta}\left[n \sin^2\,\theta + \cos^2\,\theta\right]$$

which is the same as equation (6.)

If the rafter is uniformly loaded the resultant of the load would pass through the center of the rafter. Calling the load W and proceeding in the same way as above, we find for the *resultant compression at B*

$$\frac{W}{\cos\,\theta}\left[\tfrac{1}{2} \sin^2\,\theta + \cos^2\,\theta\right]$$

$$= \frac{W}{2 \cos\,\theta}\left[\sin^2\,\theta + 2 \cos\,\theta\right]$$

which is the same as equation (11.)

The compression at any point may be formed in the same way by considering the resultant of the weight between A and the point.

ON THE FLOW OF WATER IN RIVERS AND CANALS.

By J. Farrand Henry, Ph. B.

(Continued from page 348.)

In Table XII the observed velocities on these verticals and the ordinates of the parabola are given. The ordinates of other curves have been added for comparison with these observations.

These curves were calculated by the following formulæ:

Parabola. $x = V - (b\,v)\,\frac{1}{2}\left(\frac{y-d}{D}\right)^2$;

in which x = the ordinate at any depth, y,
v = the mean velocity of the river,
V = the velocity at the depth of the axis,
d = the depth of the axis,
b = a constant, the value of which for rivers is given as 0·1856.

Introducing the constants, we have for the

St. Clair, $x = 3{\cdot}580 - 0{\cdot}771\left(\frac{y-5}{45.4}\right)^2$, and for the

St. Lawrence, $x = 1{\cdot}499 - 0{\cdot}491\left(\frac{y-5}{65{\cdot}2}\right)^2$.

Reversed Parabola. $x^2 = C + \frac{x^2 y}{y}$; in which x and y have the same value as the last; and for the St. Clair, x = 2·5, y = 47·8, C = 1·591. For the St. Lawrence, x = 0·624, y = 65·2, C = 0·950.

Logarithmic Curve. $x = C + y\,\frac{1}{a}$; x and y being the same. C = 1·800, a = 0·77, for the St. Clair, and C = 0·790, a = 2·45, for the St. Lawrence.

Ellipse. $x = C + \frac{B}{A}(2\,A\,y + y^2)\,\frac{1}{2}$; for the St. Clair, A = 57, B = 2·7, C = 1·300, and for the St. Lawrence, A = 83, B = 0·75, C = 0·818.

These last curves are the same as those plotted in figures 11, 12 and 13.

The straight lines were taken as intersecting at six-tenths the depth.

Noting first the St. Lawrence observations, we see that in that slow current the ordinates are so small in proportion to the depth that all the curves approximate very nearly to a straight line, and therefore there is but little difference in their agreement with the observations; though even in this case we see that the parabola is the worst form of curve to express the decrease in the velocities.

But in the St. Clair observations, where the velocity is more than double, and the depth much less than that of the St. Lawrence, we see at once how entirely it disagrees with the observations both at the

TABLE XII.

ST. CLAIR RIVER.—DEPTH FROM 44 to 47 FEET.

Depth of Observation.	Velocities. Feet per second.	Parabola. Humphreys and Abbot.		Reversed Parabola. Woltmann.		Logarithmic Curve. Funk.		Straight lines, intersecting at 0·6 depth. Defontaine.		Ellipse. Racourt.	
		Ordinates of Curve.	Difference from Observations.	Ordinates of Curve.	Difference from Observations.	Ordinates of Curve.	Difference from Observations.	Ordinates of Lines.	Difference from Observations.	Ordinates of Curve.	Difference from Observations.
	3·868	3·564	—0·304	4·091	+0·223	3·952	+0 084	4·000	+0·132	3·964	+0·096
5	3·907	3 573	—0·334	3 957	+0·050	3·886	—0·021	3·892	—0 015	3·916	+0·009
10	3 821	3·564	—0·257	3·814	—0·007	3·812	—0 009	3 784	- 0 037	3·843	+0 022
15	3·709	3·536	—0·173	3·662	—0·047	3·725	+0·016	3·676	—0·033	3 744	+0·035
20	3·608	3·489	—0·129	3·476	—0·132	3 623	+0·015	3·568	—0 040	3·618	+0·010
25	3·496	3·423	—0·073	3·318	—0·178	3·501	+0·005	3·460	—0·036	3·460	- 0·036
30	3·309	3·339	+0·030	3·117	—0·192	3·342	+0· 33	3 260	—0·049	3 260	—0·049
35	3·100	3·237	+0·137	2·885	—0·215	3·121	+0·021	2·943	—0·057	3·005	—0·095
40	2·678	3·115	+0·437	2·604	—0 077	2·751	+0 073	2·627	—0 051	2·671	—0·007
42·4	2·388	3·050	+0·662	2·431	+0 043	2·420	+0·032	2·475	+0·087	2·447	+0·041
45·4	1·428	2·962		2·051		1·800		2·300		2·060	
Sums	33 884	33·890	2·536		1·164		0·309		0·537		0·400
Means			0·254		0·116		0·031		0 054		0·040

TABLE XII—*Continued.*

ST. LAWRENCE RIVER.—DEPTH FROM 64 to 67 FEET

Depth of Observation.	Velocities. Feet per second.	Parabola. Humphreys and Abbot.		Reversed Parabola. Woltmann.		Logarithmic Curve. Funk.		Straight lines, intersecting at 0·6 depth. Defontaine.		Ellipse. Racourt.	
		Ordinates of Curve.	Difference from Observations.	Ordinates of Curve.	Difference from Observations.	Ordinates of Curve.	Difference from Observations.	Ordinates of Lines.	Difference from Observations.	Ordinates of Curve.	Difference from Observations.
	1·542	1·496	- 0·046	1·574	+0·032	1·537	—0·005	1·560	+0·018	1 548	+0.006
5	1·533	1·499	—0·034	1·550	+0·017	1·521	—0·012	1·537	+0 004	1·536	+0·003
10	1·509	1·496	- 0·013	1·524	+0·015	1·506	—0·003	1·514	+0·005	1 521	+0·012
15	1·507	1·487	0 020	1·497	—0·010	1·490	—0 017	1·491	—0 016	1·495	—0·012
20	1·470	1·473	+0·003	1·469	—0·001	1·470		1·468	—0·002	1 483	+0·013
25	1·477	1·453	—0·024	1·440	—0·037	1·450	—0,027	1·445	—0·032	1 458	—0·019
30	1·417	1 427	+0·010	1·408	—0·004	1·426	+0 009	1·422	—0·005	1 429	+0·012
35	1·398	1·395	— 0·003	1·374	—0·034	1·399	+0·001	1·399	+0 001	1 394	—0·004
40	1·357	1 358	+0·001	1·327	—0·030	1·367	+0 010	1·373	+0 016	1·364	—0 003
45	1·315	1·314	—0·001	1·296	+0·019	1·328	+0·013	1·296	—0·019	1·307	—0·008
50	1·236	1·265	+0·029	1 250	+0·014	1·277	+0·041	1·219	—0·017	1·249	+0·013
55	1·167	1·210	+0·043	1·195	+0 028	1·207	+0 040	1·143	—0·024	1·178	+0·011
60	1·092	1·150	+0·058	1·127	+0·035	1·087	—0·005	1·066	—0·026	1·078	—0·014
62·5	0 800	1·080		0·950		0·790		0 985		0·818	
Sums	18·020	18·025	0·285		0·271		0·183		0·185		0·130
Means			0·022		0·021		1·014		0 014		0·010

surface and bottom. Probably, were the true velocities of the Mississippi known, the differences between them and this parabola would be much greater.

The reversed parabola also differs considerably from the measured velocities; while the logarithmic curve, the straight lines intersecting at six-tenths the depth, and the ellipse, agree very well with the observations. The straight lines cannot be correct near the bottom, on account of the more rapid decrease in the velocities there; to give a close approximation to that part of the velocities, there should be a third line, still more inclined, intersecting the second near the bottom. In the selected vertical from the St. Clair the logarithmic curve appears a little the best; but in the deeper verticals, where the velocity for a considerable depth differs but little from that near the surface, the ellipse shows a much better agreement with the observations; for near the extremity of the minor axis the curve approximates to the tangent at that point.

The great discrepancy shown by the parabola naturally leads us to examine more carefully the manner of obtaining it, especially as we have seen that in full two-thirds of the selected verticals of the Mississippi observations the maximum velocity is at or near the surface.

As has already been stated, Capt. Boileau found that in his observations on the experimental canals at Metz, the decrease in velocities was best expressed by a parabola with its axis at the surface. As these observations are rather curious they are exhibited in figure 13. The velocity below the surface first increases rapidly, then follows closely a vertical line to about one-third the depth, then decreases towards the bottom in nearly a straight line; thus agreeing with M. Defontaine's two straight lines, except that their intersection is at one-third the depth, which is much higher than is given by any other observations.

In the Mississippi Report (page 251) these observations are given, reduced to English feet; and the authors found that a parabola with the axis about two-tenths the depth below the surface would agree nearly as well with the observations as one with its axis at the surface, and besides express the decrease above the point of maximum, which Capt. Boileau thought followed in law. This parabola is shown by the full lines in figure 13.

In December, 1859, about a year after the close of the Mississippi observations, Lieut. Abbot made a series of float observations, on a

feeder of the Chesapeake and Ohio canal, at the Little Falls of the Potomac.*

They were very nicely and carefully executed, and are as good as any double float observations can be, and would probably, in such a small stream, give a very near approximation to the true velocity of the current. These observations are plotted in figure 14, being represented by the circumscribed dots.

The canal was rectangular, about 23 feet wide and 7 feet deep.

According to the law of the descent of the maximum velocity, it should be found at about two-tenths the depth below the surface, which is a little less than is given by the observation.

By rejecting the surface and lowest measurement, a parabola similar to the one found to agree with Capt. Boileau's observations would pass very near to the other points. This parabola is shown by the dotted line.

An ellipse, represented by the full line in the figure, passes through the lowest observation, and agrees nearly as well as the parabola with the remainder, while it cuts the bottom at an acute instead of an obtuse angle.

It is to be regretted that this curve was not chosen rather than the parabola, for it certainly better expresses the decrease of the subsurface velocities in flowing water.

Mean Velocity.

Many engineers have attempted to find the ratio between the mean velocity of rivers and canals and the maximum velocity at the surface. Some have been contented with a simple expression of the ratio, and the equation $v = 0{\cdot}8\ V$ is generally adopted, in which $v =$ the mean velocity of the current, and $V =$ the maximum surface velocity. Dubuat gives the formula $v = \frac{V+W}{2}$, W being the bottom velocity. Young makes $v = V + 05\sqrt{V + 0{\cdot}25}$, V being given in inches per second.

Prony found $v = \frac{V\,(V + 7{\cdot}78188)}{V+10{\cdot}34508}$, but this gives generally too large a value for v.

Baumgarten multiplied it by 0·8, to make it agree with his observations on the Garonne. The formula then becomes

* Mississippi Report, page 253.

$$v = \frac{0{\cdot}8\ V\ (V + 7{\cdot}78188)}{V + 10{\cdot}34508}$$

the velocities being expressed in feet per second. In this form it will probably give a very close approximation to the mean velocity of rivers.

But the great desideratum has been a formula by which the mean velocity could be obtained from the cross section and inclination of the bed. Almost every writer on this subject has given a new formula, and proved the incorrectness of all those which were established before him.

The oldest and simplest of these formulæ is that of Chezy, $v = C\sqrt{R\,I}$, R being the hydraulic mean radius, or the cross section a divided by the perimeter p. In large rivers this quantity, R, differs but little from the mean depth. I = the inclination of the bed of the stream per running foot, or the fall, h, divided by the distance in feet, l.

C = a constant to be determined by experiment.

The value of this constant has been differently estimated by different writers, varying from 0·68 to 1·00.

Dubuat, from his own observations on small canals and a few others, deduced his celebrated formula,

$$v = \sqrt{R - 01}\left(\sqrt{\frac{307}{\frac{1}{3} - \frac{1}{2}\,L\left(\frac{1}{3} + 1{\cdot}6\right)}} - 0{\cdot}3\right)$$

L being the hyperbolic logarithm, or the common logarithm, multiplied by 2·3025851.

When R and I are both very great, the formula may be written,

$$v = V\,R\left(\sqrt{\frac{307}{\frac{1}{3} - \frac{1}{2}\,L\,I}} - 0{\cdot}2\right) \text{ nearly.}$$

Dr. Young, in his experiments upon the circulation of the blood, found that the resistances could not be expressed by the simple square of the velocity, and he modified Dubuat's formula as follows:

$$v = \sqrt{\frac{R\,I}{b} + \frac{c^2}{b^2}} - \frac{c}{b}, \text{ in which } b = {\cdot}0000001\left(413 + \frac{75}{d} - \frac{1440}{d + 12{\cdot}8} - \frac{180}{d + 0{\cdot}355}\right), \text{ and } c = {\cdot}0000001\,\frac{900\,d^2}{d^2 + 1136} + \frac{1}{\sqrt{d}}\left(1085 + \frac{13{\cdot}21}{d} + \frac{1{\cdot}0563}{d^2}\right); \text{ d = four times the hydraulic mean depth.}$$

For large rivers $v = \sqrt{20000\,d\,I}$ nearly.

He gives a table of the values of b and c for all ordinary stream and canals. In this and in Dubuat's formula the quantities are expressed in inches, and in all others, in feet.

Eytelwin's well-known formula, the one most commonly used in practice, especially by German engineers, partly on account of its extreme simplicity is, $v = \frac{10}{11}(10560\ R\ I)^{\frac{1}{2}}$.

Darcy and Bazin's formula for streams with natural beds, deduced from their own and preceding observations is, $v\ \frac{\sqrt{R\ I}}{A.}$

A being $= 000085\left(1+\frac{4{\cdot}15}{R}\right)$. For beds of cement, plank, &c., the value of A is different.

Humphrey's and Abbot's formula, obtained from measurements in the small rectangular feeder of the Chesapeake and Ohio Canal and from the selected Mississippi observations, is as follows:

$v = \sqrt{0{\cdot}0081\ b + \left(\frac{225\ a\ \sqrt{I}}{p+B}\right)^{\frac{1}{2}} + 0{\cdot}09\sqrt{b}\Big)^{2}}$, in which

B = the width of the stream and

$b = \frac{1{\cdot}69}{\sqrt{R+1{\cdot}5}}$

In 1868, after discussing the observation of MM. Darcy and Bazin, Gen. Abbott added a second term to this formula $\frac{24\sqrt{v'}}{1+P}$.

v' = the value of the first term in the expression for v. He has also prepared tables to facilitate the computation. Dr. Hazen, collating all the observations from which the above formulæ were deduced, and computing the constants by means of the method of least squares, gives the following: $v = 4{\cdot}39\sqrt{R} \times \sqrt[6]{I}$.

The above are a few of the formulæ which have been deduced by different engineers; each one first showing that none of the previous formulæ would conform to their theories and experiments.

At the commencement of this century, Dr. Robinson, of Edinburg, speaking of the state of the science of hydraulics in his day, says: "As to the uniform course of the streams which water the face of the earth, and the maxims which will certainly regulate this agreeably to our wishes, we are in a manner totally ignorant.

Who can pretend to say what is the velocity of a river of which you tell him the breadth, depth and declivity? Who can say what swell will be produced in different parts of its course, if a dam or

wier of given dimensions be made in it, or a bridge be thrown across it; or how much its waters will be raised by turning another stream into it, or sunk by taking off a branch to turn a mill? * * * * * * * * * Yet these are most important questions. The causes of our ignorance are the want or uncertainty of our principles; the falsity of our theory which is belied by experience; and the small number of proper observations or experiments, and the difficulty of making such as shall be serviceable."

Dupuit says:* "The comparison of velocities, observed in large bodies of running water is far from confirming the preceding formula;" and he also says that M. Menard states in his "*Cours de Construction*," that he found the actual outflow at a certain point in the river Meuse to be 33·4 m., while Prony's formula, applied to different sections, gave 53 m., 56 m., 74 m., 69 m., 34 m. and 29 m. At another point the computation gave 28 m., 11 m., 30 m., 39 m. and 4m., while the actual discharge was 25 m., 5."

Hints how to use a Grindstone. By T. E. Mitchell, *Phila.*

1st.—Don't waste the stone by running it in water; but if so, don't allow it to stand in water when not in use, as this will cause a soft place.

2d.—Wet the stone by dropping water on it from a pot suspended above the stone, and stop off the water when not in use.

3d.—Don't allow the stone to get out of order, but keep it perfectly round by the use of gas-pipe, or a hacker.

4th.—Clean off all greasy tools before sharpening, as grease or oil destroys the grit.

5th.—Observe—When you get a stone that suits your purpose, send a sample of the grit to the dealer to select by, a half ounce sample is enough, and can be sent in a letter by mail.

* Etudes théoriques et pratiques sur le mouvement des eaux, par I. Dupuit, Paris, 1863, page 55.

Chemistry, Physics, Technology, etc.

ON THE MINERAL RESOURCES OF NORTH CAROLINA.

By Fred'k A. Genth.

(Continued from page 48.)

Copper.—Copper ores have been found in many localities throughout the State, in the veins of the old gneissoid rocks, as well as in the more recent slates, and even in the triassic formation.

The principal ore is chalcopyrite or copper pyrites; and there is every reason to believe that many of the mines require only a fuller development to enable them to furnish large quantities of valuable ores.

I have already mentioned that many of the gold veins are associated with pyritic ores, and in fact almost all the North Carolina copper mines in the central Counties have first been worked for gold, and there are hardly any mines in Guilford, Cabarrus and Mecklenburg Counties occurring in the gneissoid and syenitic rocks, which do not show strong indications of copper ores.

When mining operations receive a new impetus, it is to be hoped that this very important fact will be borne in mind, and that no mine should be started without sufficient means to develop it at once to such a depth that a workable body of copper ores may be reached.

The general character of these mines is that about at water level, the so-called brown gold ores are replaced by quartz richly charged with iron pyrites more or less mixed with copper pyrites, the latter increasing as the mine deepens, and in many places becoming the only, or the predominating ore, and forming a regular copper vein.

The ores either became poor in gold or the latter could not be extracted by the ordinary process, then chiefly in use in North Carolina—Chilean mills and arastra—therefore many valuable mines were abandoned, mostly before a larger and paying quantity of copper ores had been reached.

In this formation there is not at present a single copper mine in operation, although many look favorable for further development.

The principal mines which promised to change into copper mines are: in Guilford County, the Fisher Hill, the North Carolina, the McCulloh, Lindsay, Gardner Hill, Twin Mines, etc.; in Cabarrus

County, the Ludowick, Boger, Hill, Phœnix, Orchard, Vanderburg, Pioneer Mills, etc., and in Mecklenburg the McGinn, Hopewell, Rudesill, Cathay Mines, etc.

The cupreous minerals observed in these mines are, near the surface, small quantities of native copper and cuprite, the latter sometimes in beautiful needles, the so-called chalcotrichite, malachite, rarely azurite, chrysocolla and pseudo-malachite, and in some of the mines chalcocite and barnhardtite; all resulting from the decomposition of chalcopyrite or copper pyrites, which forms the principal ore. Siderite or carbonate of iron often forms an important gangue rock.

A very important copper region extends through many of the western counties of North Carolina, which is best developed in Jackson, Watauga, Ashe, Wilkes and Alleghany Counties. The ores occur in hornblendic slates and gneissoid rocks.

In Jackson County, at the Savannah, the Cullowhee, the Wolf Creek Mines and others, large quantities of chalcopyrite or yellow copper pyrites have been obtained; at Elk Knob, in Ashe County, the ore consists of chalcopyrite with pyrrhotite, in a gangue rock consisting of a dark colored micaceous quartzite. The Ore Knob in the same County has furnished chalcocite or copper glauce.

At Gap Creek Mine, in Wilkes County, the ore consists of quartz with bornite or variegated copper ore and chalcopyrite. The ore sometimes contains silver and gold.

The Peach Bottom Mine in Alleghany County has been worked to a depth of 150 feet, and has produced a considerable quantity of ore; galenite occurs in a portion of the vein.

This whole mining region is well worthy the attention of capitalists, and when better facilities for transportation are offered, I have no doubt that it will be more fully and profitably developed.

The only two copper mines in North Carolina, which are worked at present to a limited extent, are in the so-called taconic slates.

The Clegg Mine in Chatham County is a large quartz vein in argillaceous slates. It is developed to a depth of 200 feet and has furnished large bunches of valuable ore. The ore is chiefly chalcopyrite, but other cuprose minerals have been found, among which azurite in small but beautiful crystals. The mine is in excellent order, and the machinery is of the best quality and very efficient. I understand that arrangements have been made to smelt the ores on the spot. Copper ores under similar circumstances are found at other places in Chatham, also in Person County.

The other mine is the so-called Emmons or Davidson copper mine, about six miles from Lexington. It has also been opened as a gold mine, but the ore was poor, containing not over thirty-seven cents per bushel, with a large admixture of iron and copper pyrites, occurring in a dark bluish green chloritic slate. It has been abandoned therefore as a gold mine and is worked only for copper. I learned a few days ago that works for the extraction of the ore by the humid way are in contemplation.

Almost identical in appearance, but richer in gold, is the so-called Barnhardt vein of Gold Hill. In the neighborhood of Gold Hill are several localities which have yielded rich copper ores; especially the Union copper mine in Cabarrus, about one mile from Gold Hill; it was worked more than any other in the neighborhood, and has furnished crystallized copper and cuprite, and a mixture of chalcocite and chalcopyrite and other ores.

Other mines in the neighborhood of Gold Hill, also several in Randolph and Davidson Counties, contain more or less copper; for instance, the Conrad Hill, show strong indications of copper.

Arsenic, Antimony and Bismuth.—Only a few ores of arsenic and antimony have been noticed in North Carolina. Amongst these is very rare native antimony, of which a small piece was submitted to my examination by Dr. Hunter, of Cottage Home, Lincoln County. It has been found in a small vein in Burke County. An examination proved it to be quite pure.

Both arsenic and antimony are found in combination with other metals: arsenic at a few localities in Union and Gaston Counties, in small quantities, as arsenopyrite or mispickel, associated with gold ores; and both arsenic and antimony in the highly argentiferous tetrahedrite of the McMakin, and the tetrahedrite of the Ludowick mines in Cabarrus County.

Bismuth has been observed as bismuthinite in minute particles associated with the gold and copper ores of the Barnhardt vein at Gold Hill, and by Dr. Asbury as bismuthite with gold ores at the Asbury mine in Gaston County; also as bismite, or teroxide of bismuth, in the same mine, and in combination with copper, lead and sulphur at Col. White's mine in Cabarrus County, probably as aikinite. The most interesting ores are the telluride of bismuth (tetradymite) and the tellurate of bismuth (montanite)—both found associated with gold ores in numerous localities—in Davidson, Cabarrus, Gaston, McDowell and

Burke Counties. The bismuthic gold mentioned by Shepard as coming from Rutherford, is probably an artificial product resulting from the simultaneous amalgamation of gold and tetradymite.

Cobalt and Nickel.—Small quantities of these two metals have been observed in the manganese gossans of several mines in Gaston County, but thus far no regular workable deposit has been found.

Manganese.—The regular manganese deposits are as yet known in North Carolina; small quantities of pyrolusite, psilomelane and wad have been observed associated with iron, gold and silver ores, in several localities in the State. Many of the iron ores contain a small per centage of manganese.

The *manganese garnet* may become of considerable importance in the iron industry; it occurs in several large veins or beds. At Buckhorn it is associated with the magnetic iron, and serves as a valuable flux, it is also found near Danbury in Stokes county, in Rowan and Rutherford counties.

Chrome.—Minute quantities are found in the magnetic iron belt passing through Guilford and Rockingham Counties. Deposits of considerable magnitude exist in the chrysolite beds of Jackson, Mitchell, Yancey and Watauga Counties.

None of them are worked at present.

Iron.—Although the mineral wealth of North Carolina is affirmed beyond a doubt by its numerous mines and deposits of gold, copper, silver and other metals, still its greatest resources consist in its vast iron ore beds, distributed throughout the entire State; and when these are properly developed; their importance will by far exceed any other mining interest.

It may be safely predicted that, at an early day, North Carolina will stand foremost as an *iron*-producing State; not only because the various varieties of iron ore exist in inexhaustible quantities, but also because they are of very superior quality, and offer all those requisites to making the better and more desirable grades of *iron* and *steel.*

The principal ores are: the pure magnetic iron, the titaniferous and chromiferous magnetic iron, menaccanite or titaniferous iron, hematite or specular iron, limonite or brown hematite, and carbonate of iron. These ores, especially the magnetites and hematites, being

in reality only a more ferriferous portion of the stratification form strings of large lenticular beds in the rocks, here and there interrupted but extending for many miles, and in some instances stretching across the entire State.

The outcrops of those ore beds being so very numerous, I cannot do more than indicate the various ranges and the localities where the ores are best developed.

But as there are also many places from which I have seen very fine ores, which require fuller investigation as to quantities, I will mention the locality, in the hope that this may lead to important discoveries. For the sake of convenience, I will commence with the most eastern locality, and take up the different nearly parallel beds in succession, up to the Tennessee line.

One mile east of Gaston, near the Roanoke River, there occurs a granular variety of hematite, more or less mixed with red and yellow ochre. The ore is apparently of very fine quality, but nothing is known as to whether it exists in quantities or not; if found in abundance, its location would make it valuable.

A large deposit of brown hematite occurs in the slate formation connected with quartzites, four miles west of Smithfield, Johnson County, and a bluff of limonite is exposed at Whitacker's, seven or eight miles south-west of Raleigh, in argillaceous and chloritic slates.

The various iron ore deposits of Chatham and Moore Counties are of much greater importance.

At Buckhorn, on the Cape Fear River, a large bed of granular magnetite has been developed, from which, if I am correctly informed, about 6000 tons of very superior iron have been produced. The bed is between 20 and 30 feet thick, and lies almost horizontally between micaschist. This magnetite is associated and largely intermixed with manganesian garnet, which serves as a flux, and renders it very easy to smelt. The iron was used during the war for car-wheels, and was of such excellent quality that one of the wheels, coming accidentally into the possession of a firm in Wilmington, Del., induced them to purchase the property, with a view to establish similar works in North Carolina. The beds dip slightly to the south-east, and appear to extend in this direction, and also to the south side of Cape Fear River.

A number of beds of hematite or specular iron make their appearance in Chatham County, in the argillaceo-talcose slates; the ores are the compact and granular hematite, of reddish, greyish and iron-black color, sometimes laminated, foliated and micaceous.

In Moore County, 12 miles east of Carthage, near Governor's Creek, there occurs a pure massive kidney-shaped hematite, without admixture, probably the south-west continuation of one of the Chatham ore beds.

On Ore Hill, in Chatham County, not only red hematites are found, but also large beds of brown hematite or limonite. This hill is between 200 and 300 feet high, and perhaps two or more large veins of about 10 to 15 feet in thickness, intersect the hill in an E. and W. direction.

The limonites are of fine quality, but their appearance and geological position would indicate that they are merely "gossans," or decomposed pyritous ores, and the probability is that at a greater depth the unaltered sulphides will be found. Since my return from North Carolina, the Ore Hill has been sold for $150,000, and there is a prospect that the old furnace on the place will soon be rebuilt and be put into blast.

The Evans ore bed is from six to eight feet wide, and has been traced for nearly one mile; it is about four or five miles from the Gulf, and consists of red hematite, of fine quality. Kelley's ore bed and several others show the same character.

The ores which I have seen are excellent, but none of them are worked.

Beds of granular magnetic iron, of fine quality, have also been found not far distant, but none of them are developed. One, for instance, is about 2 — 3 miles north of Evans ore bed.

I cannot leave Chatham County without mentioning the peculiar ores which, many years ago, have been much speculated upon as being of immense value, I mean the so-called *Black Band* ores interstratified with the coal. There are three seams of this black band between the coal beds. One of these seams is six feet in thickness, and consists of argillaceous carbonate of iron in balls and layers.

Unfortunately, only a very small quantity of this ball ore could be selected which would be pure enough for the manufacture of iron. The *great mass* contains such an abundance of bones and teeth of saurians and fishes, that the amount of phosphoric acid in the same renders it absolutely worthless as an iron ore; the quantity of phosphoric acid is so great, that it has been proposed to apply it to the soil as a manure.

A band af red hematite, probably the continuation of one of the Chatham County beds, passes through Orange County. It is quite

prominent on a hill about 1½ mile north-west of Chapel Hill. The surface is covered with ore, some of it almost pure sesquioxide of iron. Like Pilot Knob, in Missouri, it forms a series of quartzose bands, frequently with bands of pure ore alternating with quartz more or less mixed with ore.

North-east from it, in the same County, at Red Mountain, extensive beds of this ore have been discovered.

In Montgomery, Randolph and Alamance Counties, several iron ore beds have been found, which at a future day may become of importance.

Six or seven miles south-west of Troy, a band of hematite lies between bands of auriferous slates, bordered on one side by quartzite, on the other by slaty pyrophillite. It forms a mass of about 50′ wide, which has been traced for quarter of a mile. The bed is traversed by massive hornblende.

About four miles north of Troy a series of magnetic iron ore beds occur in the neighborhood of Carter's Gold Mines. The ore is frequently crystallized, friable, and is intermixed with talc and quartz. The continuation of some of these ore beds pass through Randolph and Alamance Counties, where they yield ores of most excellent quality, as, for instance, three or four miles south-west of Franklinville, where an abundance of fine magnetite is found on the surface in the immediate proximity of a vein, and at La Grange; at the latter place there also exist large deposits of bog iron ore.

Some of the most important developments have been made within the last two years by the North Carolina Centre Iron and Manufacturing Company, of this city, not only in the great titaniferous iron belt which passes principally through Guilford and Rockingham Counties, and extends through the edges of Forsythe and Davidson Counties, but also in numerous outcrops forming parallel ranges with this formation.

I have already mentioned the accumulation of iron ore in the gneissoid rocks of the Greensboro' Belt.

The ore forms one or more strata between the rocks, and their extent has been proved for about 30 miles. Near the north-eastern extension the ore beds present a remarkable character, as proved by Prof. J. P. Lesley. He has shown the beds to be outcrops of the same synclinal basin, the so-called Tuscarora range being the south-east outcrop, with a north-west dip, while the so-called Shaw range is the north-west outcrop, with a south-east dip. The ore is a granular

magnetite, more or less mixed with a micacceous mineral, also with hematite or menaccanite, and in some places it is associated with granular corundum or emery.

The average yield of the ore is 55 per ct. of iron; it contains, as I have already mentioned, small quantities of chrome, cobalt and manganese, and on an average about 13 per ct. of titanic acid, equal to 8 per ct. of titanium.

This titanic acid is not chemically combined with all the ore; in some of the varieties I have succeeded in separating, by the magnet, ore which was almost free from it, leaving the not magnetic menaccanite behind.

During the war, it was worked in bloomeries on a small scale, about two miles from Friendship, Guilford County, on a place which is now called Tuscarora, and has produced a quality of iron which was very remarkable for its toughness, its great strength and adaptation for the manufacture of steel.

Almost in range with these ore beds, magnetites as well as titaniferous iron ores have been found at several places in Mecklenburg County: the first, eight or nine miles from Charlotte, of Steel Creek Church; also, about seven miles from the same town, on the York road; and the titaniferous ore near the old Harris mine, 12 miles south-east of Charlotte. It cannot at present be ascertained whether these ores are connected with those of Guilford County.

Before I proceed with the consideration of the numerous iron ore beds of the slates of the Kings' Mountain group, I will mention that north-west of the titaniferous iron ore ranges of Rockingham, Guilford, etc., Counties, at least three ranges have lately been found between it and the Dan River, called the Johnny Watson, Love and McQuillan ranges. No developments have been made as yet, but the analyses of some of the ores show them to be free from titanic acid, and yielding about 50 per ct. of iron.

A very extensive and important belt of iron ores, which has furnished the greater portion of the iron used in the State, occurs in the slates of the King's Mountain group. It consists of a series of parallel magnetite ore beds extending, with frequent interruptions, from the neighborhood of Danbury in Stokes County, across the entire State into South Carolina.

The character of this series of magnetite beds is so uniform that it would be tedious to enumerate all the important beds; I will therefore point out only a few of the most characteristic ones.

The ores are granular magnetites *without titanic acid*, at times quite pure, but generally in part altered into hematite, and more or less intermixed with fine grained actinolite, tremolite, talc or chlorite and frequently associated with small quantities of epidote. The average of the ore is above 60 per cent.

A very fine bed of this granular magnetite associated with actinolite is the Rogers ore bank, near Danbury in Stokes County, which has been worked for a long time, and the ore smelted at the furnace on the Dan river.

There are several parallel ore beds; the upper is of the finest quality and most valuable. It is between seven and twenty feet in width, yielding on an average about 60 per cent. of iron. The ore is almost free from phosphorus and sulphur. Some of the smaller beds at their outcrop are rather sulphurous. Similar very fine beds occur in Surry County; the ores are schistose granular magnetites, with talcose, micaceous and quartzose admixtures.

At Tom's Creek this ore has been worked since 1795, and bloomeries are now in operation. Other ore beds, which also have been extensively worked, are the Williams' Ore Bed and the Hyatt's Mine.

The southern continuation of the ore beds of Stokes and Surry are developed again in Forsythe and Yadkin Counties. The character of the granular magnetites remains the same, and is an association of talc or actinolite. They have been extensively worked at Hobson's in Yadkin County, near the east bend of the Yadkin River and other places.

Probably the beds in Davie County, on the South Yadkin River, are the same, and pass through Iredell County near Statesville into Catawba and Lincoln Counties, where they have again been extensively worked for a long time in blast furnaces, as well as in bloomeries, producing iron of great strength and toughness.

In Gaston County the same beds of granular magnetite, to a great extent altered into hematite, with a fine grained actinolite slate, have been worked on the High Shoal property on the Little Catawba River, at Ellison's and Carson's Ore Banks.

Not only magnetites furnish the material for the production of iron, but also very fine limonites, fibrous, cavernous and partly resulting from the alteration of carbonate of iron, often yet showing its crystalline structure. They occur in large veins or beds in the slates; as they result mostly from the oxidation of pyritous ores, it

may be expected that at a greater depth this will replace them entirely. The Orman and Mine Mountain and Ferguson Ore Banks, all on the High Shoal property, have been extensively worked. It is to be regretted that litigations have thus far prevented Admiral Wilkes from commencing operations at this highly valuable property, with its magnificent water power and other facilities for conducting a large manufacturing business. Near the top of Crowder's Mountain a vein of specular iron has been found. In the vicinity of King's Mountain the magnetic ores have been worked since the latter part of the eighteenth century. One of the ore beds is about forty feet thick. Besides the magnetites there are also limonites of good quality. A very striking feature of this very important and extensive belt of magnetites is its proximity to a parallel band of limestone, which accompanies the iron ore at almost every locality from Danbury down to King's Mountain.

Entering again the gneissoid rocks, we meet near Newton in Catawba County a very valuable bed of granular magnetic iron in syenite, resembling the ore from Cranberry in Mitchell County.

Magnetites as well as hematites are found in Wilkes and Caldwell Counties, some of which were formerly manufactured into iron. One very promising outcrop of large beds of fine granular *titaniferous* magnetite, for instance, has been observed near the Yadkin River, one mile west of Patterson, and another two miles north of Hickory, both in Caldwell County. At the latter place there also occurs red hematites and limonites in large deposits and of excellent quality. It is probable that further developments may prove the existence of a more extensive range, since similar granular magnetites have been found near Morgantown, almost in a line with the strike with the more northern beds.

Another bed accompanies the limestone of McDowell county on both sides of the North Fork of the Catawba River; the ores are limonite sometimes also hematite mixed with magnetite. These limonite beds continue to the west of the Blue Ridge, where we find them again overlying the limestone in Henderson and Transylvania Counties.

Several beds of limonite and occasionally hematite of good quality, exist in several localities of Buncombe county, so at Ore Mountain, two miles south west of Swannanoa Gap, and also 4—5 miles west of Ashville.

The magnetites and hematites west of the Blue Ridge deserve the

highest attention, as they are not only of very superior quality, but also found in inexhaustible quantities. The most northern bed of magnetites is found in Ashe County at the North Fork of New River, near Hilton Creek. The ore is granular and talcose, in its general character almost identical with the ores of the King's Mountain range, being granular magnetites of somewhat slaty structure from the intermixture of small quantities of talc. The ores have been worked in bloomeries and have yielded a good quality of iron.

A very superior ore occurs at Cook's Gap in Watauga County. It consists of an almost pure stratified red hematite with octahedral crystals of magnetite disseminated through the mass. It is associated with limonite. It is an ore worthy of fuller investigation.

A number of iron ore beds are found in Mitchell County; the most valuable deposits are about one and a half miles south of Cranberry, near the Tennessee line. The ore beds have not been sufficiently explored to show their geological character and size, but they appear to be inclosed between hornblende slates and a peculiar micaceous slate.

The size of the ore beds must be enormous; judging from the outcrops it may have a width of 300—400 yards, and extends for more than half a mile; the whole side of the hill is covered with large blocks of the finest quality of magnetite, which evidently exists there in inexhaustible quantities.

The magnetite is often quite pure and polaric, coarse-grained, sometimes crystallized in octahedra, and associated with pyroxene and epidote. The pyroxene weathers into a brown ferruginous clay, in which are inclosed grains of magnetite. As these ores are soft and require little labor, they are the *only* ones worked and converted into blooms, at the works about two miles distant. The whole production is not over one ton of blooms a day. The finest quality is not touched. The analysis of a specimen representing about the average character of the ore, showed it to be entirely free from sulphur and phosphorus, and containing ·65 per cent. of iron.

There are several promising outcrops of magnetic ore beds in Mitchell County, but most of the other ores are menaccanite, which occurs at the following localities: at Crab Orchard, Cane Creek and Flat Rock.

In Madison County, on the east Fork of the Big Laurel, a large ourcrop of slaty fine grained granular magnetites, of apparently very good quality occurs, also a highly titaniferous menaccanite, containing

nearly 38 per cent. of titantic acid. A bed of specular iron exists at Jewell Hill.

Other beds of magnetic ores in the same county occur in hornblende slates near Fines Creek in Haywood, and in garnetiferous micaschist at several points in Macon County.

I have yet to mention the immense beds of limonite or brown hematite, which occur in several localities in Cherokee County, associated with the limestone or marble and talc, one of which is worked, about one mile from Murphy.

The ore is of very fine quality, compact, also porous and fibrous, in some places ochreous; the quantity is inexhaustible, and beyond doubt the region where these deposits exists will sooner or later become a large iron manufacturing district.

Coal. The great abundance of iron ores in North Carolina requires for their reduction a large amount of fuel, and the question of its supply has for a time given a great deal of anxiety to those who are most largely interested in the manufacture of iron, as under the present system of forest destruction, instead of cultivation, the manufacture of charcoal iron must eventually be abandoned, although this may not take place for hundreds of years yet to come. It is therefore of the greatest importance that North Carolina contains several kinds of coal, some of which are of excellent quality, and in the immediate neighborhood or within a short distance only of the most valuable iron ore deposits.

I have already stated that the North Carolina coal does not belong to the so-called carboniferous period, but to the triassic; it is of the same age as the coal near Richmond, Va.

In Chatham and Moore Counties is the south-eastern extension, generally called the Deep River Coal Field; in Rockingham and Stokes Counties the north-western of the same beds, or the Dan River Coal Field. The centre is washed away.

From the investigations of Prof. Emmons and Admiral Wilkes, we learn that the Deep River coal is of the best quality, well adapted for the manufacture of iron and gas, and can be obtained in inexhaustible quantities.

The area underlaid by coal is over forty square miles, containing over 6,000,000 tons of coal to each square mile. The coal measures consist of strata of slates, calcareous shales, alternating with beds of argillaceous carbonate of iron and seams of coal, all inclosed between two beds of red sandstone.

Five seams of coal have been observed; the upper consists of a bed of six and a half feet in thickness, separated by a seam of black band. Near the outcrop it is somewhat contaminated with sulphur, which diminishes, however, as the depth increases. There are several varieties of coal, the highly bituminous and semi-bituminous; near a trapdyke it has lost almost the whole of its volatile matter and has become an anthracite. According to an analysis of coal from the deep pit at Egypt, by Dr. Jackson, it contains:

Fixed Carbon	= 63·6
Vol. Matter	= 34·8
Ash	= 1·0

An analysis of Egypt coal, which I have lately made, gave:

Moisture	= 0·84
Vol. Matter	= 25·75
Fixed Carbon	= 63·27
Ash	= 10·14
	100.00 per cent.

It contained 1·35 per cent. of sulphur.

An analysis of coal from the Gulf gave me:

Moisture	= 1·16
Vol. Matter	= 21·90
Fixed Carbon	= 70·48
Ash	= 6·46
	100.00 per cent.

Sulphur only 1·02 per cent.

All these analyses show the great value of the Deep River coal.

The Dan River coal field embraces an area of over thirty square miles; it has hardly been developed. Small quantities have been mined near Madison, Rockingham County, which were used by the blacksmith in the neighborhood; and the North Carolina Centre Iron and Manufacturing Co., of this city, has made a few trial pits which have proved the existence of five beds of coal, although it is probable that there are others besides.

The coals which I have examined from two of the seams near the outcrop gave respectively, 11·44—13·56 per cent of ash, 75·96 and 76·56 per cent. of fixed carbon and about 12 per cent. of volatile matter. These results are very encouraging. The Dan River coal field being the north-west continuation of the Deep River, has probably the same seams, and, where the coal is undisturbed, the same quality of coal. These coal fields are not only of general value, but, when it is re-

membered that they lie in close proximity to some of the largest and best iron beds in the State, their importance can then be fully appreciated.

Diamond and Graphite. North Carolina possesses carbon, not only in the form of several varieties of coal, but also in its two other modifications, as diamond and graphite.

Both occur in the old gneissoid rocks, the graphite in beds interstratified with the micaschist or gneiss; the diamond in the débris of such rocks, associated with gold, zircon, garnet, monazite and other minerals.

It is very remarkable that these two minerals are found in strata of the same age; and this fact reminds me of an analogous one, which may throw some light on their origin, viz., in producing the adamantine boron we always obtain the graphitic form at the same time.

Diamond has not been observed in North Carolina in any more recent strata, and in the itacolumite regions *no* diamonds have ever been found, as in Brazil; from which it appears that the itacolumite of Brazil is either simply a quartzose micaslate of similar age with the North Carolina gneissoid rocks, or that, if it is cotemporary with the North Carolina itacolumite, the diamonds were not *produced* in the same but came from older rocks, and were re-deposited with the sands resulting from their reduction to powder and are now found imbedded in the same, their hardness having preventing their destruction. Seven or eight diamonds have thus far been found. They occur distributed over a wide area of surface in the counties of Burke, Rutherford, Lincoln, Mecklenburg and Franklin, and I have no doubt, if a regular search would be made for them, they would be found more frequently. Some of the stones were fine crystals of first water; their weight was from one half karat to about two karats.

Graphite, so much in demand now for the manufacture of crucibles for melting steel and other metals, for lead pencils, as an anti-friction agent, for stove blacking, paint, &c., is found in numerous localities in the State.

The largest beds known since nearly half a century occur a few miles west of Raleigh in Wake County. There appear to be two belts about half a mile apart; the beds contain several seams of greater purity from six to eighteen inches in width. The beds are known to extend for a distance of eighteen or twenty miles.

It has been explored seven miles north-west of Raleigh, and a shaft

has been sunk to a depth of one hundred feet. It is mostly mixed with fine grit and is rather slaty, and would require mechanical means for the separation of the impurities. Other beds of graphite, but not so extensive, are found in Lincoln, Caldwell, near Hickory, and in Burke Counties near Morgantown. None of them are developed. The best quality which I have seen came from Alexander County, three miles from Taylor's, and from Cane Creek in Person County.

Sulphur is not found in North Carolina, except occasionally in small crystals, in cavities of quartz, resulting from the decomposition of pyrite. A large supply of sulphur ores will be furnished when the mines of the State are worked to a greater depth. One large vein of pure iron pyrites occurs in Gaston County. Most of the other veins will furnish in addition gold and copper.

Corundum.—Corundum, which, on account of its hardness, is so much sought for as a cutting and polishing material for hard substances, has been found, in a state of great purity and abundance, at several places in the neighborhood of Franklin, in Macon County, in connection with granites and chrysolite rocks.

It is mostly greyish or brownish, but sometimes it assumes a beautiful sapphire blue and ruby color. It is to be regretted that the blue has not yet been found in pieces large enough to be cut for gems, and that the ruby has not the requisite trasparency. A large boulder of dark blue corundum was found, many years ago, near the French Broad River, in Madison County. It has lately been observed on the Burnsville Road, 19 miles from Ashville. In small quantities it is found at Crowder's and Clubb Mountains, Gaston County.

The granular corundrum or emery is associated with the magnetites of the great titaniferous iron range in Guilford County.

Rutile.—Titanic acid, in the form of rutile, used in the arts to give a peculiar color to artificial teeth, is found in considerable quantity at Crowder's and Clubb Mountains, in Gaston County; also at several localities in Mecklenburg and Mitchell Counties.

Mica, Feldspar, Kaoline, Pyrophyllite.—Hundreds of years ago, long before the Indians occupied the territory of North Carolina, many excavations were made in the numerous large coarse-grained granite beds of Mitchell, Yancey, Cleveland and other Counties. In the year 1867 a number of these old mines have been taken up again, and now mining, on a somewhat extensive scale, is going on, and a

great portion of the mica used in the arts for stoves, lamp-shades, window-panes, etc., comes from Mitchell and Yancey Counties, North Carolina. The mica has mostly a slightly brownish color; it occurs, irregularly distributed, through the granite, in rounded pieces, some of them weighing several hundred pounds. It is then split and cut into marketable shapes, which, according to size, will sell from $1 — $10 per pound.

The same localities furnish a very fine quality of orthoclase or potash feldspar, used for glazing porcelain and for artificial teeth.

At some of the mines in Mitchell County the orthoclase is almost completely decomposed, and leaves frequently a snow-white kaoline or porcelain clay. It is found at several other localities, as in Lincoln, Burke and Macon Counties.

In the region of the Deep River, in Chatham and Moore Counties, very extensive beds of pyrophyllite slate have been worked for a long time.

It is sometimes called agalmatolite, from the fact that from a dense variety of the same rock the Chinese cut and carve their little images, idols and toys. The North Carolina mineral, being entirely free from grit, is largely used as an antifriction material, also for the lining of furnaces, slate-pencils, in the manufacture of wall-paper, as a cosmetic, and for other purposes. Other, though less extensive, beds have been found in Montgomery and Gaston Counties.

Serpentine, Talc.—Only one locality has come to my notice from where a serpentine could be obtained fit for ornamental purposes. It has a dark greenish-black color, contains very small seams of a greenish chrysolite, with silky lustre, and acquires a good polish. Found in large quantities 1½ mile below Patterson, in Caldwell County.

The serpentine found in the chrysolite beds west of the Blue Ridge are of no value.

The most beautiful white, or greenish-white massive, or finely crystallized talc is found, in inexhaustible beds, in many places in Cherokee County.

It is used for similar purposes as the slaty pyrophyllite of Chatham and Moore Counties. Massive and schistose talc, or soapstone, suitable for fire-places, mantle-pieces, stove-linings, etc., is found in many localities in the State.

Barytes.—This material, when quite white much used as a paint, and more generally for the adulteration of "*white lead*," is found in

abundance and excellent quality at several localities. A coarsely granular variety, white, like marble, is found in Union County; another similar one, massive and granular, in a vein from 7 to 8 feet in thickness, in Gaston County, at Crowder's Mountain; and a greyish-white laminated variety, at the Latta mine, near Hillsboro', in Orange County. West of the Blue Ridge it is found, in white granular masses, at Chandlers', nine miles below Marshall, in Madison County.

Alum and Copperas.—Many of the gneissoid slates of Cleveland, Rutherford and other Counties contain large quantities of pyrite finely disseminated through them, which, by oxidation, or weathering, produces copperas and alum, both of which were therefrom manufactured on a large scale during the war.

Marble.—Only in one or two localities in the limestones of Stokes and Catawba Counties, a fine-grained variety is found, which would be useful for ornamental purposes if the quantities were not too limited. West of the Blue Ridge, however, in Cherokee and Macon Counties, it is found in large beds, of the finest qualities. There is not only the fine-grained white, resembling that of Carrara, but also the greyish-veined marble, like the Italian, and a most beautiful variety of a fine pink hue.

The limits of this paper are already far beyond my original expectations; and still I might add many more details which would be of interest. In as concise a form as possible, I have indicated and described the principal valuable minerals in the State, and the localities where they occur. I have dwelt rather more fully upon gold, copper, iron and coal, because of their greater importance, especially the two latter, which I believe will prove a source of immense wealth to the State.

My various visits to North Carolina, and more particularly the opportunities afforded me for observations during my trip there last summer, have enabled me to collect many facts and much data relative to the various mines and mining districts, which doubtless would be of interest, but which want of space compels me to omit for the present. I hope, however, that at some future day it will again be my privilege to present the Franklin Institute with further observations on this interesting subject.

Philadelphia, December, 1871.

THE CHEMICAL THEORY OF THE VOLTAIC BATTERY.

By J. P. Cooke, Jr.

(Continued from page 412.)

ELECTRICITY.

17. *Characteristics of Electrical Polarity.*—The familiar phenomena of electricity are the manifestations of a polar condition of matter, which, in several respects, is closely allied to magnetic polarity. Thus electrical polarity determines effects of attraction and repulsion similar to those produced by a magnet, although the force exerted is far more feeble. So also electrified bodies—that is bodies electrically polarized—induce a similar condition in all neighboring and susceptible masses of matter, and the phenomena of electrical induction closely resemble those of magnetic induction. There are, however, two distinctive features of electrical polarity, which appear more or less in all electrical phenomena, and determine most marked differences between electrical induction and the corresponding phases of magnetic polarity.

In the first place, a ready susceptibility to electrical polarity is, as far as we know, a universal attribute of matter, and not limited, like magnetism, to a few substances. All bodies are *electrics* (that is, susceptible of electrical polarity) to a greater or less degree, and the difference between what we familiarly call conductors and non-conductors of electricity is similar to the difference between soft iron and steel, in their relations to magnetism. When we electrify a mass of glass or resin the body under favorable conditions retains its polarity for a short time, but on a mass of brass we cannot excite even a transient polarity, unless the body is insulated from all surrounding conductors by some non-conducting support. Otherwise the polarity almost instantly spreads through the contiguous conductors, and the body becomes thus reduced to the state of the great mass of the earth, which everywhere acts as a general leveler of electrical polarity.

In the second place, electrical polarity may not only be imparted to neighboring bodies by induction, when, as in magnetic induction, the inducing body sustains no loss of energy; but it may also be transferred from one insulated conductor to another by contact; the gain of the one body being attended with a corresponding loss to the other, as the word transfer implies.

18. *Theory.*—All phenomena of electrical transfer forcibly suggest the inference that electrical polarity is not an affection of the molecules themselves, but of an atmosphere surrounding the mole-

cules, which is capable of separation and hence of transfer. This polarized material appears to be a highly elastic medium, co-existing with the luminiferous ether in the molecular atmospheres, and without attaching to the words any more definite meaning than this, we may call the material in question the *electrical fluid or ether*, and speak of electricity as a highly attenuated form of matter, to which the terms relating to quantity are strictly applicable. According to the view then here adopted, electrical phenomena are manifestations of the polar condition of a medium, which envelopes the molecules of all known substances, and the vitreous and resinous, or positive and negative, electricities of the old theory are two of the constituents of this atmosphere, which, as we suppose, is held about the molecules just as the air is retained upon the earth. It is also supposed that in the normal state there are present in the atmosphere of every molecule, definite proportions of these two constituents (or perhaps merely opposite conditions) of the ether perfectly intermingled, but that by various causes a more or less complete separation of the two may result, determining the phenomena of electrical polarity. Again, without attempting to explain the nature of the difference between these two inconvertible etherial substances (or states of the same material) we recognize the existence of a strong tendency to a perfect blending of these elements of the ether as the cause of the phenomena of electrical currents. Further, our theory assumes that the blending of the two opposite electricities is a phenomenon of the same class as that of the diffusion of gases, only taking place with vastly greater rapidity on account of the very great elasticity of the etherial medium. Lastly, it assumes that the atmospheres are held around the molecules by a molecular attraction, which is capable of coping with their enormous elasticity, and that while these atmospheres merge in the general etherial medium in which molecule and planet alike float, the electrical elements of the ether, being more readily compressible than the luminiferous constituent, are limited to the neighborhood of the ponderable molecules, around which they are condensed.

19. *Electrical Conduction and Induction.*—The distinctive characters of electrical polarity we have pointed out, explained by the theory of the last section, indicate clearly the nature of the difference between the polar phenomena, which appear in electricity and magnetism. Thus, while the magnetic condition simply spreads through a mass of magnetic material, placed in contact with a magnet, we recognize in the corresponding electrical phenomenon, which we call an electrical

current, not only this molecular induction, but also an actual transfer of what we call electricity from molecule to molecule through the long line of conductors, and the whole order of the phenomenon reminds us of a flowing fluid. So also while in magnetic induction the intervening material or diamagnetic appears to be wholly passive, we find that in electrical induction the dielectric under the same conditions is strongly polarized.

Indeed, Faraday supposed that in all cases of electrical induction, the polar condition spreads from one conductor to the other through the intervening molecules of the insulator, which he called the *dielectric*, and, if so, this mode of electrical action does not differ essentially from the spreading of magnetism through a rod of iron, and is simply the condition antecedent to that transfer of the electric fluid, which distinguishes the electrical current. And although it may be an open question whether the polarity of the dielectric is an essential condition or only an incidental effect of the polarity induced in the associated conductor, it must be admitted that, in all known cases of electrical induction, the intervening molecules of the dielectric are unquestionably polarized, as must necessarilly be the case, seeing that all matter is electrically susceptible, and that the circumstances of the phenomena are exactly those which Faraday's theory would require.

20. *Statical Charge of Electricity.*—In magnetism the polarized material appears to be inseparable from the molecule, and, in consequence, each molecule is a perfect magnet, having its opposite polarities exactly balanced, and capable, therefore, of returning to the neutral condition by itself alone when these parts react on each other. It is very different with electricity. Here the transfer of the polarized ether from molecule to molecule may lead to the accumulation, at determinate points, of one or the other of the two polarized states of the electrical ether, and hence disturb the polar-equilibrium of the molecule. Thus these two opposite conditions of the ether, which we call respectively vitreous and resinous, or positive and negative, electricities may be to a greater or less degree isolated, and a body is said to be *charged with vitreous or resinous electricity*, when one or the other preponderates in the atmospheres of its molecules taken as a whole.

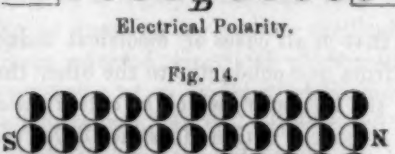
As might be expected, therefore, the ordinary type of electrical polarity differs widely from that of magnetic polarity, and involves at least three different bodies, viz., two conductors and an intervening

dielectric. As the type of magnetic polarity was represented by Fig. 4, repeated below (Fig. 14) for the sake of comparison, so the ordinary type of electrical polarity, as manifested in the so-called statical phenomena of electricity, may be represented by the diagram of Fig. 13. Here C and C′ are the surfaces of two conducting bodies insulated from each other by the dielectric D. In the body C, we will assume there is an excess of vitreous or positive electricity, which for the reason we shall soon see, is accumulated on the molecules at or near the surface, and in C′, there is an exactly equivalent excess of resinous electricity distributed in a similar way, while between them we have the polarized molecules of the dielectric.

Fig. 13.

Electrical Polarity.

Fig. 14.



Magnetic Polarity.

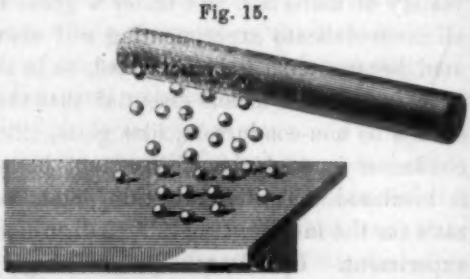
If the dielectric admitted of no transfer of the electric fluid between the two conductors, the condition above represented would be as permanent as is the polarity of a magnet. But this is not the case with any dielectric known, and there is always a more or less rapid transfer of the electric ether from molecule to molecule, through the insulating material until the opposite polarities are neutralized, and the whole system restored to the normal condition. In other words every insulator is a conductor to a limited extent, and the transfer of electricity through the material of the dielectric is simply a slow electrical current. Moreover it will be noticed that a charge of electricity necessarily implies an equal and opposite charge on some neighboring conductor or conductors, and that the polar condition of the intervening dielectric depends on the opposition of these charges, for so great is the mobility of the electrical ether that electrical polarity cannot, like magnetic polarity, persist for an instant on a conductor, after the inducing cause ceases to act.

21. *Current of Electricity.*—The lines of material molecules, through which a transfer of the electrical ether is taking place, as between C and C′ in Fig. 13, form the channel of what we call an electrical current. An electrical current is frequently compared to the flowing of water through a pipe, and the conditions, which regulate the amount of flow, are so similar in the two cases that the anal-

ogy is of great value in rendering the more obscure phenomena intelligible. It must be remembered, however, that an electrical current is not the continuous motion of a mass of matter in a single direction, but the reciprocal transfer of the electrical ether between the molecules of the conductor, the two electricties passing in opposite directions at the same time; so that while one-half of the whole charge at C in Fig. 13 passes to C′, one-half of the whole of the charge at C′ passes to C. This transfer implies, as we shall hereafter see, an oscillation of the molecules of the conductor, which determines a wave motion throughout its whole extent, and some of the most important effects of the current may be referred to this mechanical action. It will be best, however, to defer the further discussion of the subject until we have applied our theory as already developed, to the explanation of some of the more familiar facts of statical electricity.

22. *Attraction and Repulsion.*—The very word electricity derived from the Greek name for amber (ἤλεκτρον) suggests, as the first object of inquiry, one of the most familiar manifestations of electrical energy, indeed the only phenomenon of the class known to the ancients, and still a fundamental fact of the science. When a piece of amber of any other resinous substance is rubbed against a woolen surface, it acquires the property of attracting light bits of straw or paper. The experiment is now usually made with a common stick of sealing wax rubbed against the coat sleeve; but, for class illustrations, it is best to employ a large baton of the same material, easily made by casting the wax over a paste board core,* while a skin of cat's fur, which can be obtained from a furrier, makes an excellent rubber. The baton is held in one hand, and, when excited by friction against the fur held in the other, is then brought near some small balls made of alder pith. These are first attracted and afterwards repelled, and then alternately attracted and repelled, producing a very lively action as represented in Fig. 15. In order to illustrate still more fully the principles involved in this familiar experiment, it is best to provide further: 1, a metallic sphere about six inches in diameter,

Fig. 15.



* A cylinder of card board covered with thin sheet gutta percha is an admirable substitute for the baton of sealing wax.

mounted on an insulating stand; 2, a glass tube about two inches in diameter by three feet long, together with a silk pad—coated with the usual amalgam—for rubbing it; and 3, two toy balloons of india rubber, which should be fastened by short silk threads to moveable blocks of wood, resting on the table so that the balloons shall float on a level with the spherical conductor, see Fig. 16.

Fig. 16.

If, now, we stroke the balloons with the cat's fur they will soon become highly electrified, both necessarily in the same mode, and on bringing them together they will repel each other. If next we electrify the sealing wax by rubbing with the fur, it will be seen, on bringing the baton near the balloons, that they are both repelled by it, but on the other hand the glass tube, after being electrified by friction against the amalgamated silk, will be found to attract them with equal strength. Again repeating these experiments, but insulating the rubber in either case, by interposing a sheet of gutta percha between it and the hand, and using india-rubber gloves as a still further protection, it will appear that the fur or the amalgamated silk are electrified as strongly as the resin or the glass, but that they act on the balloons in just the opposite way. Thus, while the sealing wax will repel the balloons, the fur with which it has been rubbed will attract them; so also while the glass tube attracts them the silk pad repels them.

Electrical excitement may be produced by friction with a great variety of materials, and under a great variety of conditions, but in all cases delicate experimenting will show that the two bodies associated become oppositely polarized, as in the above experiment. Moreover it is by no means essential that the materials rubbed together should be non-conductors, like glass, silk, resin and fur. Only if a conductor is used, the effect cannot be made evident unless the body is insulated. To illustrate this point, we may next stroke with the cat's fur the insulated metallic ball, which has been provided for the experiment. It will soon become highly electrified, and the polar condition may be made evident by bringing it near one of the balloons,

which will be decidedly repelled. If, however, we touch the ball with the finger, even in one place, all indications of electricity will instantly disappear, although the charge could not be wholly removed from the resin or the glass, except by passing the hand over the entire surface. Electrifying now the resin, and passing the baton over the metallic ball so that the metal may touch the resin at many points, it will be found that the baton has in part lost, and the ball acquired the power of repelling the balloons. Next, after discharging the ball with the finger, repeat the experiment, but use the glass tube in place of the baton, and notice that the ball now attracts the balloon, which it before repelled. Lastly, having again excited the resin with the fur, pass the baton over the still electrified ball, and observe that this addition of electricity, instead of increasing rapidly, lessens the attractive force until at last it wholly vanishes, when it will be found that the body has been restored to its normal state.

(To be continued.)

CYCLICAL RAINFALLS AT LISBON.

By Pliny Earle Chase, Professor of Physics in Haverford College.

Read before the American Philosophical Society, Aug. 18, 1871.

The more strongly marked and decisive character of the curves of lunar monthly rainfall in Philadelphia than in Great Britain (Proc. A. P. S., v. x, pp. 523–34), rendered me desirous of obtaining observations from some European station in lower latitude. The intimation of that desire to the Director of the "Observatorio do Infante Dom Luiz," at Lisbon, was promptly followed by the transmission of a copy of observations extending over a period of sixteen years, which is herewith presented. I also submit some of the tabulated results of such discussion of the observations as I have already undertaken, which appear to me to corroborate, in a most satisfactory manner, the views I have hitherto advanced respecting the meteorological influence of the moon. Some of the tables also afford interesting indications of a somewhat similar planetary influence, sufficient, as it seems to me, to encourage further investigation.

One of the objections most often urged against the acknowledgment of any appreciable lunar or planetary influence upon rainfall or other atmospheric phenomena, is based on the different, and sometimes contradictory, results obtained by different investigators, from observations in different places and at different times; another arises

from the difficulty of conceiving any tidal or other force adequate for the production of any considerable disturbance. Nevertheless, such of the objectors as are familiar with Howard's discussion of the moon's influence upon the barometer; Sabine's, of lunar disturbances of terrestrial magnetism; or Schwabe's and Wolf's, of the dependence of sun-spots upon planetary configurations, seem to admit—at least I am not aware that any of them deny—the probability of the conclusions which those eminent observers have severally expressed.

If it is conceivable that Saturn, Jupiter and Venus can in any way affect the cloudiness, or amount of spotted surface of the sun, notwithstanding the immense preponderance of his attractive, magnetic and other supposable forces, it is surely much more easily to imagine that they may similarly affect the meteorological phenomena of the earth, which opposes an antagonizing mass only $\frac{1}{324800}$ (according to Newcomb's estimate) as great as that of the sun. If the lunar tides of our atmosphere are of sufficient magnitude to affect the barometer, the consequent waves must effect a blending of aerial currents of different temperatures and different degrees of humidity; and in consequence of the stratification of the upper and lower winds, this blending offers a unique opportunity for the practical study of the opposite tidal tendencies in deep and shallow fluid seas or envelopes. If the lunar are as unmistakable as the solar modifications of magnetic phenomena, the analogies which have been pointed out by Messrs. Baxendell and Bloxam between magnetic and pluvial, and by myself between pluvial and auroral curves, are indicative of other possible lunar influences which are equally unmistakable. If the difficulty of conceiving an adequate cause for a supposed phenomenon were to deter us from inquiring whether an apparent dependence were real or illusory, all progress in science would become impossible. Finally, if it can be shown that solar rain-curves exhibit different, and often contradictory inflections, similar to those which are objected to in the lunar curves, and if a consistency of disagreement can be shown between the lunar results at two given stations, accompanied by a consistency of agreement between the results in different cycles at the same station, the argument from apparent contradiction will be deprived of all its force.

I have no hope of thoroughly convincing any one who is skeptical of lunar influence on the weather, by deductions from observations at one or two, or a half dozen stations, but I believe that any one who will examine, carefully and impartially, the tables I have already

published, based on observations in India, Great Britain, Portugal, Canada and different portions of the United States, will at least be willing to admit that the question is an open one. And if he will compare my previous tabulations with those which accompany the present paper, he may, perhaps, find any lingering skepticism shaken, however prejudiced or inveterate it may be.

For convenience of comparison, I represent, in each instance, the mean rainfall for the entire period under consideration by 100, and any deviation from the mean, whether of excess or deficiency, is denoted by the addition or subtraction of a corresponding percentage. The smoothing by successive means is uniform in all the tables. I invite special attention to the columns of lunar rainfall at Lisbon, in each of the first two tables, representing two different sets of three independent periods, averaging 64 months, a cycle which I have hitherto supposed too short to yield any satisfactory results. If there is no casual nexus, it is difficult to imagine any possible reason for the striking similarity between the ordinates for the different cycles, a similarity which I think quite as striking as that between the solar curves at the same station for independent periods of similar duration. If the lunar disturbances are considered as merely tidal, while the solar are partly tidal, but principally thermal, their relative magnitudes suggest interesting comparisons between centrifugal and centripetal forces analogous to those which I have hitherto had the honor of presenting to the Society.

The resemblance between the independent curves in Table III is not very marked; but the yearly mean is curiously like the yearly averages of the lunar monthly ordinates in Tables I and II, if we construct the curves so as to compare the ordinate of Jupiter's opposition, No. 16, with the ordinate of lunar conjunction, No. 1, and *vice versâ*.

The tendency to opposition between rainfall curves on opposite sides of the Atlantic, of which I have already submitted some illustrations to the Society, is interestingly shown near the solstitial and equinoctial periods, by Table IV.* Columns 6 and 7 of the same table indicate a similarity between the curves of daily and annual rainfall at Philadelphia, which lends additional interest to my comparison of pluvial and auroral curves.

* Published by permission of Prof. Benjamin Peirce, Supt. U. S. Coast Survey.

Explanation of Figures.

The horizontal lines represent the average rainfall; each vertical space represents a deviation of ·2 of the mean value; each horizontal space represents two days in the abscissas of the lunar curves, or $\frac{1}{15}$ of a year in the abscissas of the solar curves. The lunar curves begin and end with the day of new moon; the solar curves with January 1.

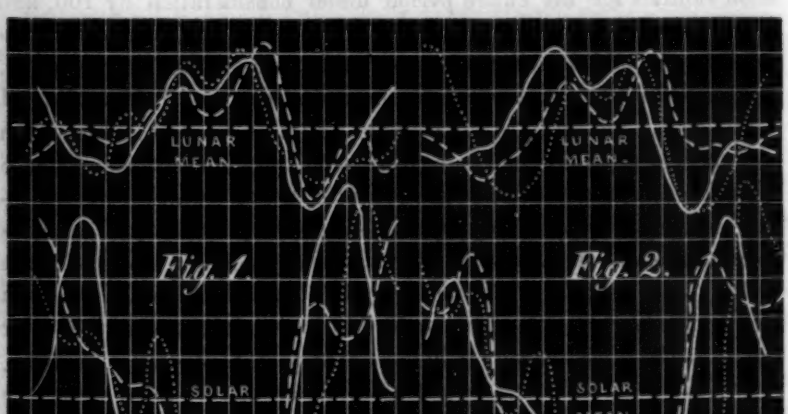


Fig. 1.—*Lunar Curves.*

December to March, inclusive; continuous line.
April to July, inclusive; broken line.
August to November, inclusive; dotted line.

Solar Curves.

1855, '58, '61, '64, '67, '70; continuous line.
1856, '59, '62, '65, '68; broken line.
1857, '60, '63, '66, '69; dotted lines.

Fig. 2.

1855–'60; continuous line.
1861–'65; broken line.
1866–'70; dotted line.

TABLE IV.
Comparative Daily and Yearly Rainfalls.

TABLE II.
Correspondent Rainfalls at Lisbon in Lunar and Solar periods.
LUNAR MONTHLY. SOLAR YEARLY.

TABLE II.

Correspondent Rainfalls at Lisbon in Lunar and Solar periods.

DAY OR YR. + 30.	LUNAR MONTHLY. 1855—60. R.	N.	1861—65. R.	N.	1866—70. R.	N.	Av. N.	SOLAR YEARLY. 1855—60. R.	N.	1861—65. R.	N.	1866—70. R.	N.	Av. N.
1	115·0	87	170·1	97	178·7	141	104	222·4	131	298·2	150	178·7	171	146
2	146·8	85	154·2	95	151·9	144	103	235·6	148	208·5	144	118 9	155	148
3	116 2	84	134 3	90	150·4	133	98	231·0	162	78·6	145	168·9	146	152
4	108·4	85	147·0	83	96 6	117	91	369 9	162	290·0	162	129·2	148	158
5	158·7	87	106 3	76	119·0	101	86	218·5	142	283·5	175	143·5	154	156
6	124·7	87	108·0	73	84·7	86	81	103·1	119	236·7	163	204·5	150	142
7	102 9	9·	102 8	77	69 6	73	81	223·8	108	226 9	128	147·0	126	119
8	158·2	99	172 8	83	53·4	66	85	162·3	105	51·6	89	50·0	96	97
9	173 5	112	93·3	87	76·0	66	91	126·6	101	73 9	71	40·7	95	90
10	162·4	126	180 3	93	73·3	69	94	209·6	97	98·6	76	134·3	118	95
11	231 9	139	120·1	103	50·9	79	110	124·2	88	140·9	85	239·9	124	95
12	235·5	145	193 6	117	98·1	99	123	111·8	74	163·5	79	46·2	91	80
13	205·2	140	264·1	124	164·5	118	128	112 5	59	52·6	56	31 4	47	55
14	216·2	128	153·6	118	102·9	125	123	75·8	40	31·4	31	5·7	21	32
15	118·1	119	152·3	109	154·8	121	116	3 9	22	11·8	15	8·7	12	17
16	194·4	121	193·6	105	91·3	116	114	15·8	10	7·7	7	13·9	10	9
17	199·1	130	136·6	108	177·6	118	118	·8	5	6·2	5	8·6	12	7
18	202·7	133	165·9	119	114·7	128	127	·3	7	·1	7	6·1	15	9
19	239 2	123	246 6	135	176·8	137	131	21·2	14	1·5	15	34·5	20	16
20	120·4	102	234·4	141	144·6	127	123	38·2	24	68·6	26	9 9	31	27
21	104·9	81	251·9	128	113·0	99	104	48·4	40	22·0	47	36·8	51	47
22	117·3	65	135·3	105	40·3	69	82	76·9	78	60·8	86	110·1	72	80
23	60·8	55	92 5	91	29·4	55	69	218·4	124	261·7	136	75·8	79	116
24	58 6	56	158·0	90	70·8	56	70	359·6	159	254·0	171	109·2	73	141
25	87·8	70	182·3	93	78·8	59	77	215·7	179	312·1	176	8·7	79	153
26	175·8	86	112 8	91	28·3	65	84	298 5	194	156 8	165	45·9	124	166
27	149·2	93	143·4	90	72·4	81	89	458·0	191	238 4	156	298·7	185	177
28	96·8	92	148·9	91	133·2	103	95	223·6	163	233 9	149	261·0	211	171
29	180·4	92	145·5	93	129 8	118	99	134 8	130	177·9	143	165·0	200	154
30	121·2	90	141·2	95	97·9	130	102	179·3	121	141 4	145	218·7	185	146

TABLE IV.

Comparative Daily and Yearly Rainfalls.

☉ R. OR YR. + 24.	PHILADELPHIA. June.	Dec.	April.	Oct	Average Daily.	Average Annual.	GREENWICH. January.	July.	April.	Oct.
1	123	92	120	114	91	92	53	92	120	99
2	111	78	130	112	91	89	54	103	143	126
3	92	72	127	103	93	89	63	107	169	148
4	77	71	118	97	98	90	66	112	179	146
5	69	71	103	106	105	91	64	118	155	122
6	71	73	86	105	110	94	65	129	110	98
7	79	81	77	105	113	99	72	139	74	82
8	84	95	78	110	113	105	74	140	60	75
9	80	102	78	125	112	110	72	136	59	79
10	68	96	70	140	109	113	78	133	63	85
11	56	87	64	143	105	112	99	128	65	82
12	55	85	67	135	102	110	127	109	66	72
13	66	90	74	117	103	109	141	89	72	65
14	92	100	82	93	106	111	131	94	86	66
15	131	116	94	71	109	112	111	126	101	76
16	172	136	111	58	108	108	97	148	115	97
17	186	144	124	55	104	101	98	129	125	121
18	162	133	124	56	98	95	116	88	124	133
19	123	113	122	65	92	91	145	56	111	129
20	98	102	125	79	87	95	170	40	90	121
21	90	106	123	97	85	96	173	30	73	112
22	92	119	106	106	87	96	150	32	66	98
23	102	124	93	107	90	96	110	49	76	85
24	118	112	101	109	91	95	72	73	98	84

TABLE I.

Different and non-correspondent Rainfalls at Lisbon, in Lunar and Solar periods, from December 1, 1854, to Dec. 1, 1870. R. = Total fall; N. = Normal percentage of rain.

DAY OR YR. + 30.	LUNAR MONTHLY. Dec. Mar. R.	N.	Apl. July. R.	N.	Aug. Nov R.	N.	Yr. N.	SOLAR YEARLY. 1855+3N* R.	N.	1856+3N* R.	N.	1857+3N* R.	N.	Av. N.
1	298 0	123	45·9	82	154·5	95	106	184·7	102	275·7	192	238·9	160	146
2	223 9	115	79·7	89	143·7	104	106	120·7	121	329·7	186	112·6	143	148
3	174·8	97	53·6	94	156·5	103	99	216 8	158	139·9	161	121·8	131	152
4	136·9	85	63·6	97	124·4	93	90	451 3	192	175·4	138	161·4	130	158
5	153·5	83	75·9	98	104·9	81	85	342·9	194	193 6	127	109·0	135	156
6	189 8	81	68·3	96	66 3	78	83	257 4	164	94·0	123	192·9	133	142
7	141·8	78	42·9	94	113·5	89	84	224·0	121	242·6	119	131·1	116	119
8	106 7	78	88·8	93	181·1	102	89	69·5	87	102 2	112	92·2	94	97
9	187·2	85	37·4	96	118·0	104	93	106·0	75	118·5	109	16 7	91	90
10	182·9	95	83·1	102	168·9	98	98	130·6	70	164·3	110	147·6	114	95
11	185·3	108	67 7	109	74·0	98	105	112 5	69	200·7	99	191·8	132	95
12	252·0	121	83 3	116	111 7	114	118	118,9	59	33·8	75	168·8	118	80
13	269·8	128	71 6	121	267·0	132	128	78·8	42	84·0	49	33·7	81	55
14	271·7	124	113·0	118	187·0	133	126	11·2	23	36·8	31	64·9	49	32
15	173·1	118	46 2	107	118·7	122	118	6·8	11	5 3	17	12·3	25	17
16	214·7	119	73·2	101	146 9	122	117	15·8	7	16·4	9	5·2	12	9
17	272 6	128	53·5	107	195·1	134	126	7 9	6	1·8	7	5·9	7	7
18	260·8	135	89·5	123	204·1	141	135	6·5	7	0·0	8	0·0	12	9
19	266 0	136	102·9	138	297·5	132	135	12·9	12	33 2	11	11·1	26	16
20	289·8	124	97·3	145	135·5	114	124	27·6	23	2·1	22	86 1	39	27
21	199·1	101	105·7	135	98·9	98	106	52·1	45	20 8	50	35·3	46	47
22	99·3	75	91·7	108	163 9	87	85	93·5	83	118·6	97	35·7	54	80
23	105·1	60	30·1	74	69·5	77	68	231·2	129	261·2	135	63 5	72	116
24	97·2	57	12·0	58	84·0	72	62	342·7	166	223·1	150	148·0	92	141
25	123·2	64	42 4	64	120·7	72	67	304·1	92	157·6	142	74·8	109	153
26	112·3	76	67·5	82	65·4	77	77	208·5	212	152·3	134	140·4	135	166
27	244 7	87	61·6	94	134·4	82	86	625 4	216	226 5	131	143·2	174	177
28	118·7	95	79 6	94	124·2	83	91	275·6	182	101·5	134	341·4	200	171
29	219·1	105	52·0	86	102·7	81	93	85·9	131	214·0	150	177·8	195	154
30	214·7	118	44 5	79	71·4	84	100	177·3	104	218·6	174	143 5	177	146

* 1855, '58, '61, '64, '67, '70; 1856, '59, '62, '65, '68; 1857, '60, '63, '66, '69.

TABLE III.

Lisbon Rainfall in Synodic years of Jupiter.

Syn. Yr. + 30.	1853—60.	1861—65.	1866—70.	Dec. Mar.	April. July.	Aug. Nov.	Year.
1	141	177	45	139	76	110	117
2	127	148	41	121	74	93	103
3	111	101	49	87	78	90	86
4	98	65	70	62	79	94	76
5	89	48	99	61	78	97	76
6	81	43	128	70	80	96	81
7	79	43	146	78	89	102	88
8	88	45	151	84	96	112	96
9	110	45	150	95	97	117	103
10	139	45	143	106	103	112	108
11	156	41	141	105	121	121	113
12	146	39	154	90	137	143	116
13	119	36	165	77	133	151	112
14	99	37	146	74	115	124	98
15	99	37	112	83	94	81	84
16	108	36	100	100	89	51	81
17	109	45	114	113	101	46	88
18	96	68	132	117	125	60	99
19	80	98	138	121	131	79	108
20	67	123	127	126	115	86	110
21	53	131	101	117	91	79	99
22	45	129	73	95	78	76	86
23	53	134	58	79	87	91	84
24	72	153	58	79	111	112	96
25	84	168	60	95	127	114	107
26	83	196	60	117	123	99	112
27	86	200	61	128	110	93	113
28	106	191	64	125	100	110	115
29	132	183	61	124	90	130	120
30	145	183	53	133	76	130	122

CONTRIBUTIONS TO THE SUBJECT OF BINOCULAR VISION.

By Prof. Chas. F. Himes, Ph. D.

(Continued from page 419.)

In the previous article, at p. 417, the statement of Prof. J. Le Conte, the writer of a series of highly scientific and interesting articles on the subject of binocular vision in Silliman's Journal, we inadvertently omitted. An implied necessity for convergence of the optic axes in binocular combination will be found in the quotation given below (p. 8, No. 7, Vol. II, Third Series, July, 1871), especially as it is nowhere else intimated that pictures whose identical points are more distant than the interocular distance can be united ocularly.

"Stereoscopic may be combined with the naked eye, *also beyond* the plane of the card in the manner of a stereoscope; but there are two difficulties in the way of success in this manner of combination. In the first place, in most stereoscopic pictures, identical points are farther apart than the eyes, and therefore cannot be combined beyond the pictures without the aid of lenses or prisms. In the second place, even if the pictures are not farther apart than the eyes, and may therefore be thus combined, the dissociation of the focal from the axial adjustment, as already explained in my first paper* is difficult and imperfect, and the combined picture is therefore not clear."

PSEUDOSCOPIC OR FALSE EFFECT, PRODUCED BY TRANSPOSING THE PICTURES OF A STEREOGRAPH.

If the pictures of a stereograph are transposed, then, viewed by means of an ordinary lenticular stereograph, or by the first ocular method given, or, if an ordinary stereograph without transposition of the pictures is viewed by the second ocular method, it is plain that the right eye will see the left eye picture, and the left eye the right eye picture. In this case quite a different and, in many respects, very interesting effect will be produced, that may be called an inversion of distances. Objects that would appear nearer, according to the usual arrangement of the pictures, would now appear more remote, and the more remote objects appear nearer. This is called *Pseudoscopic*, or false effect. In fig. 6, for example, if the diagrams L and R, which represent the frustum as seen by the left and right eyes respectively, were transposed, it is plain, according to statements made in the discussion of the methods for drawing of stereographs,

* Silliman's Journal II, xlvii, pp. 73, 76.

that a stereograph of a frustum of a cone with its larger base nearer the observer would be produced, for the corresponding points of the larger circles of the diagram would then be nearer than those of the smaller circles. Whilst the diagram above alluded to, answers well from its simplicity for the explanation of this pseudoscopic effect, it is not calculated to impress the peculiar nature of it upon the reader.

If the photographs of the stereograph of a real object are transposed, and the distances between the corresponding objects of the two pictures measured and compared, it will be found that the distance between the images of the same tree, for example, on the two pictures, will now be greater than that between the images of the same edge of a window before which it stands, instead of less, and when viewed by means of the stereoscope, as far as the two edges are concerned in assigning it a position, it should appear behind instead of in front of the window. Were there no other criteria of distance to influence the judgment in this case of a photographic landscape than that afforded simply by two eyes, this case would have no interest beyond that of the simple line diagrams of the frustum. But, as we have elsewhere explained, there is nothing in the nature of these diagrams to cause either of them alone to represent one frustum—that is, a concave or a convex—rather than another, but the play of the axes of the two edges upon them alone gives decided character to the resulting impression. The photographs of a real object, however, involve not only other monocular criteria of distance and form, but possess many of them in great perfection. The perspective, the relative sizes are accurately rendered; shading, etc., with less degree of perfection.

The struggle between the (so to speak) cumulative effect of these usual and monocular criteria of distance and the single binocular one of variation of the optic angle,—or movement of the optic axes,—placed at variance with natural effect by this arrangement of the pictures, is exceedingly interesting. As previously intimated, the binocular criterion is the most definite and absolute, yet, for a time, it will generally fail to assert itself. The face of an individual will refuse to become a hollow mask, as it should, or elevations to be converted into depressions, or trees in the foreground march back through the houses or rocks, and take their position in the rear, and be visible through the houses and rocks, imparting to them a peculiar unnatural transparency. The objects in the background scarcely succeed in

fighting their way to the front, in spite of the accurate perspective and the smallness of their relative sizes.

Any one in looking at such a picture at all closely, must feel a want of the usual satisfactoriness of stereoscopic views; he may even remark that the pictures do not unite well, and, in some cases, they may be regarded as too far apart, or the difficulty may be referred to defect of the particular instrument, until it has been tried with other stereographs. But sooner or later the play of the optic axes in passing from the points falsely represented to them as near to those with equal falsity represented as remote, overcomes all other influences upon the judgment, and the beholder yields to the deception; the objects appear turned inside out, the houses, rocks, etc., advance to the foreground and assume the unnatural transparency.

In experimenting in this way it will soon be noticed that some stereographs manifest this pseudoscopic effect much more readily and decidedly than others, that, indeed, some, especially of landscapes, do not manifest to the eye of a casual, unsuspecting and unpracticed observer any difference when mounted thus pseudoscopically. The effect may seem about as fine as when properly mounted. The reason for this is that in such pictures which generally have little foreground, and therefore few decided objects within the range of the play of the optic axes—the binocular criterion,—the geometrical perspective, relative size, and so forth, have a more decided influence upon the judgment, and overpower the, in this case, comparatively feeble binocular condition. In order to test this fact, the writer has frequently selected such views and transposed the pictures, and has found that the most practised observers with the stereoscope will frequently fail to detect the transposition. So views of long colonades, or of trees, which afford such decided geometrical perspective, will with difficulty be made to come into the new unnatural shape when the pictures are transposed.

These facts afford an additional argument for care in the selection of foreground for stereoscopic views, and explain the cause of the increased demand frequently for stereoscopic views inferior photographically and in general appearance, out of the stereoscope, to others by their side.

To such as will take the little trouble to acquire the power of uniting pictures by the second ocular method given,—by squinting to a point nearer than the stereograph,—a collection of stereographs will become a collection of pseudographs as well, without the necessity of